US009092142B2

(12) **United States Patent**
Nashimoto et al.

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(45) **Date of Patent: Jul. 28, 2015**

(54) **STORAGE SYSTEM AND METHOD OF CONTROLLING THE SAME**

(75) Inventors: **Kunihiko Nashimoto**, Ninomiya (JP); **Keishi Tamura**, Fujisawa (JP); **Hideo Saito**, Kawasaki (JP)

(73) Assignee: **Hitachi, Ltd.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 276 days.

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(51) **Int. Cl.**
G06F 9/312 (2006.01)
G06F 13/14 (2006.01)
G06F 3/06 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 3/061*** (2013.01); ***G06F 3/065*** (2013.01); ***G06F 3/067*** (2013.01); ***G06F 3/0659*** (2013.01)

(58) **Field of Classification Search**
CPC ... G06F 3/0685; G06F 3/0647; G06F 3/0665; G06F 3/067; G06F 3/0631; G06F 11/3433; G06F 11/3485; G06F 12/1475; G06F 2212/7204; G06F 11/0745; G06F 3/065; G06F 2206/1012; G06F 11/0709; G06F 11/0727; G06F 11/0757; G06F 11/30; G06F 12/00; G06F 2003/0697; G06F 2201/81; G06F 3/0689; G06F 3/061; G06F 3/0641; G06F 11/2056; G06F 2003/0698; G06F 2212/286
See application file for complete search history.

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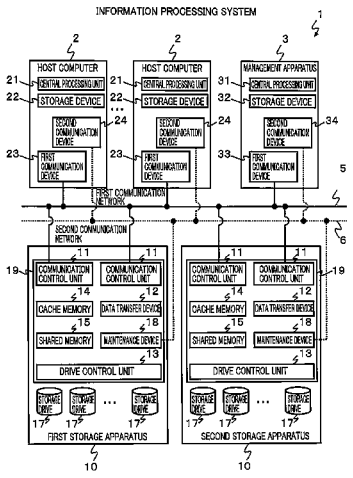
Primary Examiner — Cheng-Yuan Tseng
Assistant Examiner — Candice Rankin
(74) *Attorney, Agent, or Firm* — Foley & Lardner LLP

(57) **ABSTRACT**

For first write request to a virtual volume, the first storage apparatus performs processing by a method of either a first write processing method that stores write data in a first logical volume associated with the virtual volume as well as transfers a first write request, to the second storage apparatus, for storing the write data in a second logical volume associated with the virtual volume of the second storage apparatus or a second write processing method that transfers a first write request, to the second storage apparatus, then selects a processing method according to a first IO load on a first area of the virtual volume of the first storage apparatus and a second IO load on the first area of the virtual volume of the second storage apparatus to perform a processing for the first write request.

16 Claims, 22 Drawing Sheets



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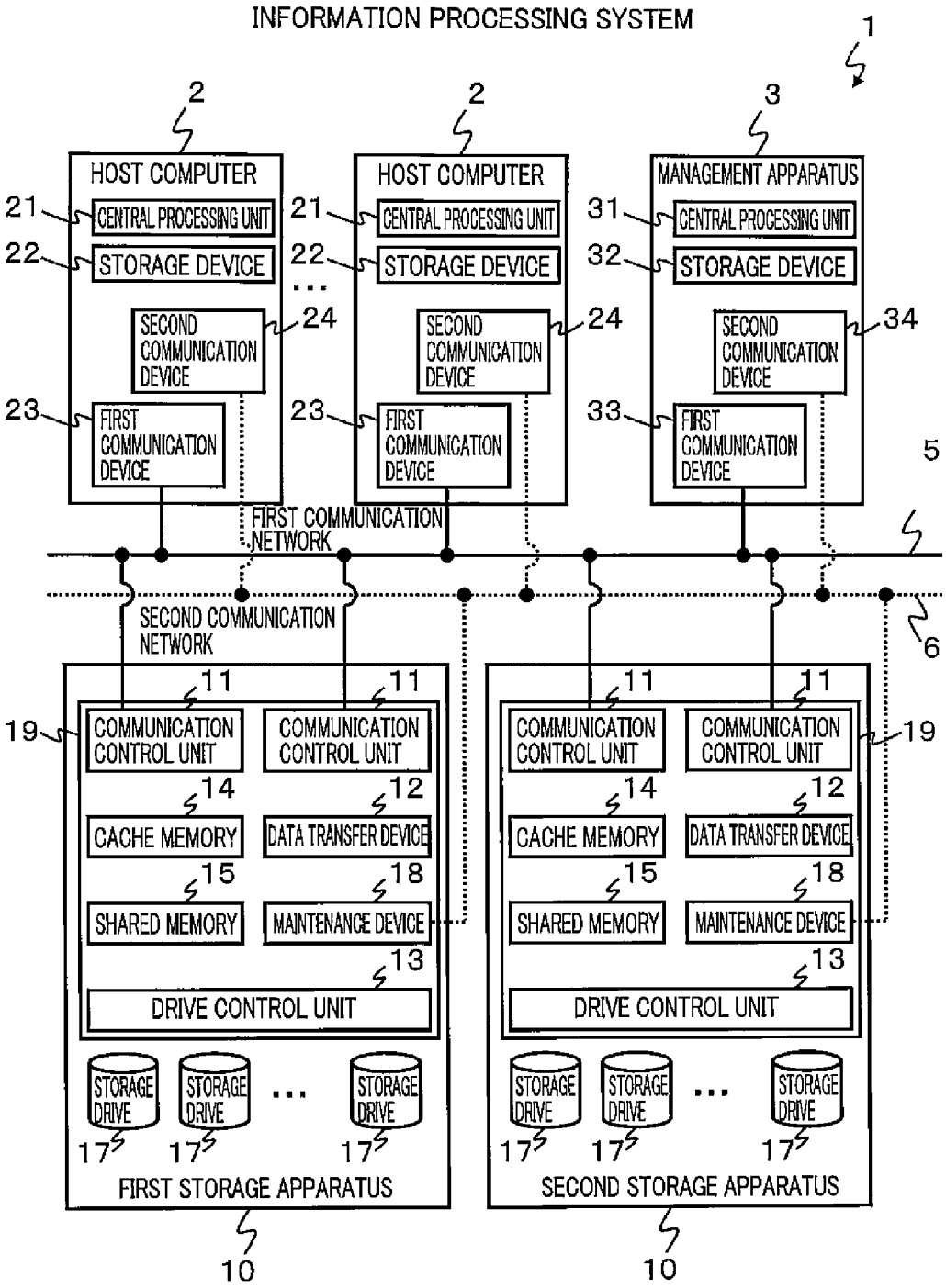
INFORMATION PROCESSING SYSTEM
1
2
2
3
HOST COMPUTER
HOST COMPUTER
MANAGEMENT APPARATUS
21
CENTRAL PROCESSING UNIT
21
CENTRAL PROCESSING UNIT
31
CENTRAL PROCESSING UNIT
22
STORAGE DEVICE
22
STORAGE DEVICE
32
STORAGE DEVICE
SECOND COMMUNICATION DEVICE
24
SECOND COMMUNICATION DEVICE
24
SECOND COMMUNICATION DEVICE
34
23
FIRST COMMUNICATION DEVICE
23
FIRST COMMUNICATION DEVICE
33
FIRST COMMUNICATION DEVICE
5
FIRST COMMUNICATION NETWORK
SECOND COMMUNICATION NETWORK
6
11
11
11
11
19
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
19
14
12
14
12
CACHE MEMORY
DATA TRANSFER DEVICE
CACHE MEMORY
DATA TRANSFER DEVICE
15
18
15
18
SHARED MEMORY
MAINTENANCE DEVICE
SHARED MEMORY
MAINTENANCE DEVICE
13
13
DRIVE CONTROL UNIT
DRIVE CONTROL UNIT
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
17
17
17
17
17
17
FIRST STORAGE APPARATUS
SECOND STORAGE APPARATUS
10
10

FIG. 1

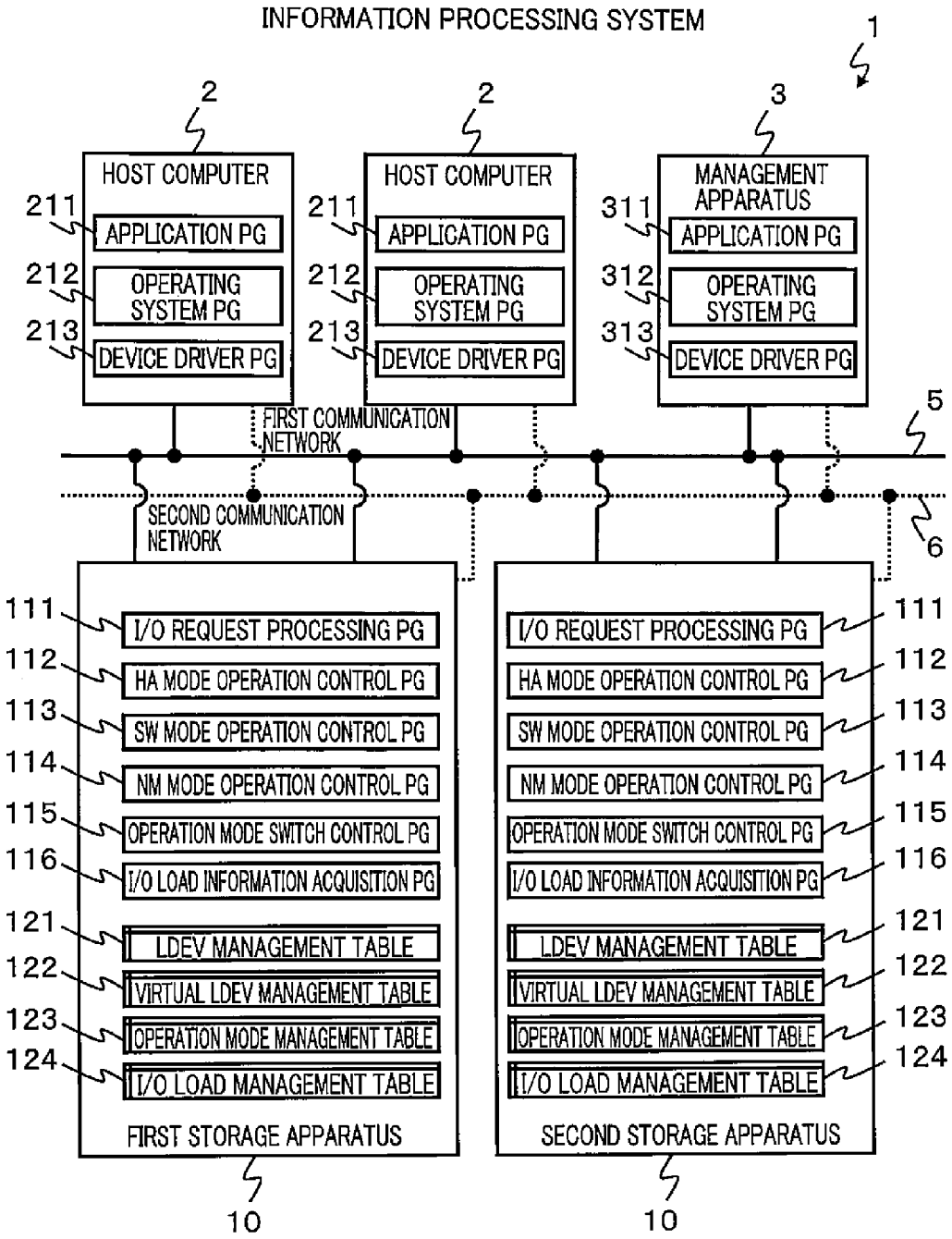
INFORMATION PROCESSING SYSTEM
1
2
HOST COMPUTER
211
APPLICATION PG
212
OPERATING SYSTEM PG
213
DEVICE DRIVER PG
2
HOST COMPUTER
211
APPLICATION PG
212
OPERATING SYSTEM PG
213
DEVICE DRIVER PG
3
MANAGEMENT APPARATUS
311
APPLICATION PG
312
OPERATING SYSTEM PG
313
DEVICE DRIVER PG
5
FIRST COMMUNICATION NETWORK
SECOND COMMUNICATION NETWORK
6
111
I/O REQUEST PROCESSING PG
112
HA MODE OPERATION CONTROL PG
113
SW MODE OPERATION CONTROL PG
114
NM MODE OPERATION CONTROL PG
115
OPERATION MODE SWITCH CONTROL PG
116
I/O LOAD INFORMATION ACQUISITION PG
121
LDEV MANAGEMENT TABLE
122
VIRTUAL LDEV MANAGEMENT TABLE
123
OPERATION MODE MANAGEMENT TABLE
124
I/O LOAD MANAGEMENT TABLE
FIRST STORAGE APPARATUS
10
111
I/O REQUEST PROCESSING PG
112
HA MODE OPERATION CONTROL PG
113
SW MODE OPERATION CONTROL PG
114
NM MODE OPERATION CONTROL PG
115
OPERATION MODE SWITCH CONTROL PG
116
I/O LOAD INFORMATION ACQUISITION PG
121
LDEV MANAGEMENT TABLE
122
VIRTUAL LDEV MANAGEMENT TABLE
123
OPERATION MODE MANAGEMENT TABLE
124
I/O LOAD MANAGEMENT TABLE
SECOND STORAGE APPARATUS
10

FIG. 2

LDEV MANAGEMENT TABLE 121
(FIRST STORAGE APPARATUS)

311 RAID GROUP ID	312 LDEV−ID
1(Drive00,01,02,03)	00:00
	00:01
	00:02
2(Drive04,05,06,07)	00:03
	00:04
:	:

FIG. 3

LDEV MANAGEMENT TABLE 121
(SECOND STORAGE APPARATUS)

311 RAID GROUP ID	312 LDEV−ID
1(Drive00,01,02,03)	10:00
	10:11
	10:12
2(Drive04,05,06,07)	10:13
	10:14
:	:

FIG. 4

VIRTUAL LDEV MANAGEMENT TABLE 122
(FIRST STORAGE APPARATUS)

411	412	413	414	415	416	417
VIRTUAL LDEV		STORAGE SYSTEM 1		STORAGE SYSTEM 2		PATH INFORMATION
VIRTUAL PRODUCTION NUMBER	VIRTUAL LDEV	FIRST LDEV	FIRST ATTRIBUTE	SECOND LDEV	SECOND ATTRIBUTE	
F0:00	11111	00:00	Master	10:10	Slave	I1-T1
F0:01	22222	00:01	Slave	10:11	Master	I3-T3
⋮	⋮	⋮	⋮	⋮	⋮	⋮

FIG. 5

VIRTUAL LDEV MANAGEMENT TABLE 122
(SECOND STORAGE APPARATUS)

411	412	413	414	415	416	417
VIRTUAL LDEV		STORAGE SYSTEM 1		STORAGE SYSTEM 2		PATH INFORMATION
VIRTUAL PRODUCTION NUMBER	VIRTUAL LDEV	FIRST LDEV	FIRST ATTRIBUTE	SECOND LDEV	SECOND ATTRIBUTE	
F0:00	11111	00:00	Master	10:10	Slave	I1-T1
F0:01	22222	00:01	Slave	10:11	Master	I3-T3
⋮	⋮	⋮	⋮	⋮	⋮	⋮

FIG. 6

OPERATION MODE MANAGEMENT TABLE 123
(FIRST STORAGE APPARATUS)

511 VIRTUAL LDEV	512 PAGE	513 OPERATION MODE	514 OPERATION MODE CHANGE PERMISSION
00:00	1(0x0000 ~0x1000)	HA MODE	Y
	2(0x1000 ~0x2000)	HA MODE	Y
	~		
⋮			
FF:FF			

FIG. 7

OPERATION MODE MANAGEMENT TABLE 123
(SECOND STORAGE APPARATUS)

511 VIRTUAL LDEV	512 PAGE	513 OPERATION MODE	514 OPERATION MODE CHANGE PERMISSION
00:00	1(0x0000 ~0x1000)	HA MODE	Y
	2(0x1000 ~0x2000)	HA MODE	Y
	~		
⋮			
FF:FF			

FIG. 8

I/O LOAD MANAGEMENT TABLE 124
(FIRST STORAGE APPARATUS)

611 LDEV	612 PAGE(ADDRESS)	613 ACCESS COUNT (TOTAL) (IOPS)	614 ACCESS COUNT (Read) (IOPS)	615 ACCESS COUNT (Write) (IOPS)
00:00	1(0x0000 ~0x1000)	2. 0M	1. 5M	0. 5M
	2(0x1000 ~0x2000)	0. 5M	0. 2M	0. 3M
	:	:	:	:
	:	:	:	:

616 OPERATION MODE CHANGE UPPER THRESHOLD (IOPS)	617 OPERATION MODE CHANGE LOWER THRESHOLD (IOPS)	618 OPERATION MODE CHANGE UPPER THRESHOLD (Read) (IOPS)
1. 0M	100	0. 5M
1. 0M	100	0. 5M
:	:	:
:	:	:

FIG. 9

I/O LOAD MANAGEMENT TABLE 124
(SECOND STORAGE APPARATUS)

611 LDEV	612 PAGE(ADDRESS)	613 ACCESS COUNT (TOTAL) (IOPS)	614 ACCESS COUNT (Read) (IOPS)	615 ACCESS COUNT (Write) (IOPS)
00:00	1(0x0000 ~0x1000)	0. 1M	0. 1M	0. 0M
	2(0x1000 ~0x2000)	2. 0M	1. 2M	1. 3M
	:	:	:	:
	:	:	:	:

616 OPERATION MODE CHANGE UPPER THRESHOLD (IOPS)	617 OPERATION MODE CHANGE LOWER THRESHOLD (IOPS)	618 OPERATION MODE CHANGE UPPER THRESHOLD (Read) (IOPS)
1. 0M	100	0. 5M
1. 0M	100	0. 5M
:	:	:
:	:	:

FIG. 10

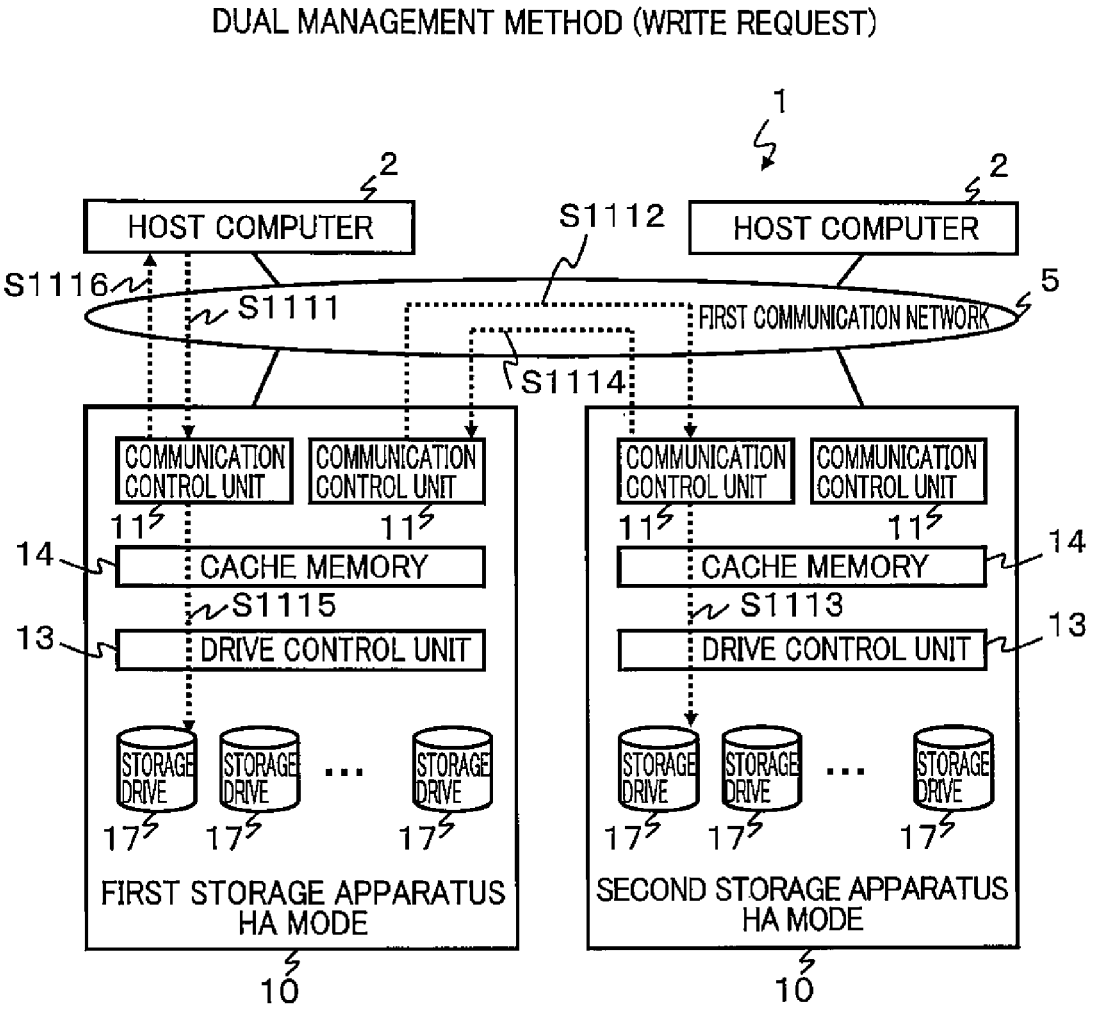
DUAL MANAGEMENT METHOD (WRITE REQUEST)
1
2
HOST COMPUTER
S1112
HOST COMPUTER
S1116
S1111
5
FIRST COMMUNICATION NETWORK
S1114
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
11
11
14
CACHE MEMORY
S1115
13
DRIVE CONTROL UNIT
STORAGE DRIVE
17
FIRST STORAGE APPARATUS
HA MODE
10
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
CACHE MEMORY
S1113
DRIVE CONTROL UNIT
SECOND STORAGE APPARATUS
HA MODE

FIG. 11

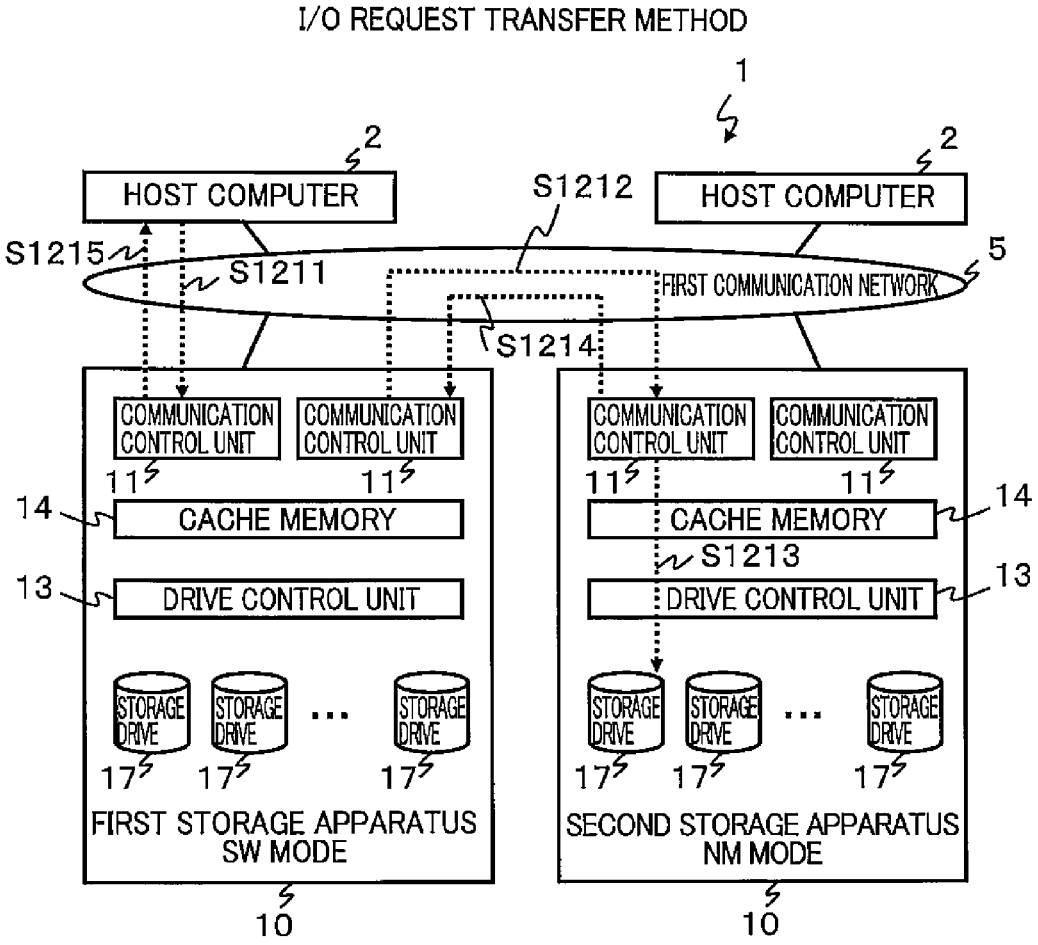
I/O REQUEST TRANSFER METHOD
1
2
HOST COMPUTER
S1212
HOST COMPUTER
S1215
S1211
5
FIRST COMMUNICATION NETWORK
S1214
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
11
11
11
11
14
CACHE MEMORY
CACHE MEMORY
14
S1213
13
DRIVE CONTROL UNIT
DRIVE CONTROL UNIT
13
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
STORAGE DRIVE
17
17
17
17
17
17
FIRST STORAGE APPARATUS
SW MODE
SECOND STORAGE APPARATUS
NM MODE
10
10

FIG. 12

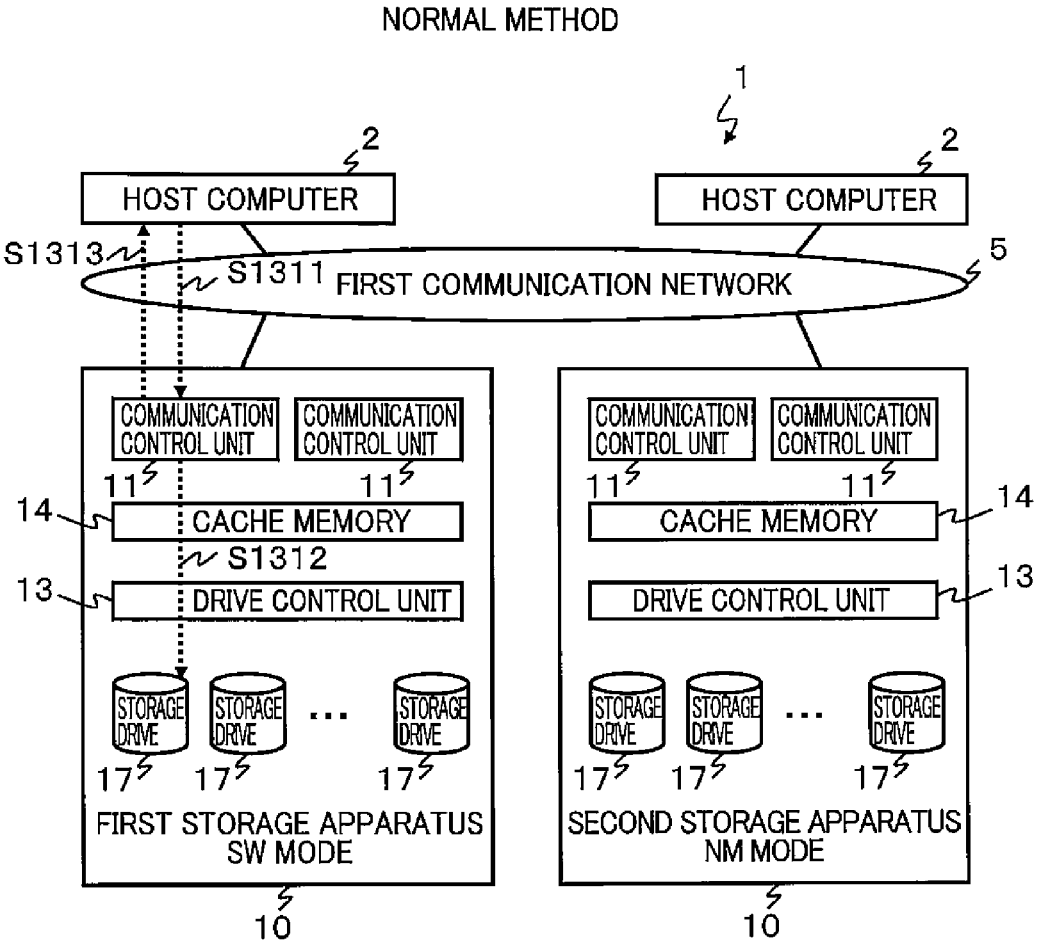
NORMAL METHOD
1
2
HOST COMPUTER
2
HOST COMPUTER
S1313
S1311
FIRST COMMUNICATION NETWORK
5
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
11
11
14
CACHE MEMORY
S1312
13
DRIVE CONTROL UNIT
STORAGE DRIVE
17
FIRST STORAGE APPARATUS
SW MODE
10
COMMUNICATION CONTROL UNIT
COMMUNICATION CONTROL UNIT
11
11
14
CACHE MEMORY
13
DRIVE CONTROL UNIT
STORAGE DRIVE
17
SECOND STORAGE APPARATUS
NM MODE
10

FIG. 13

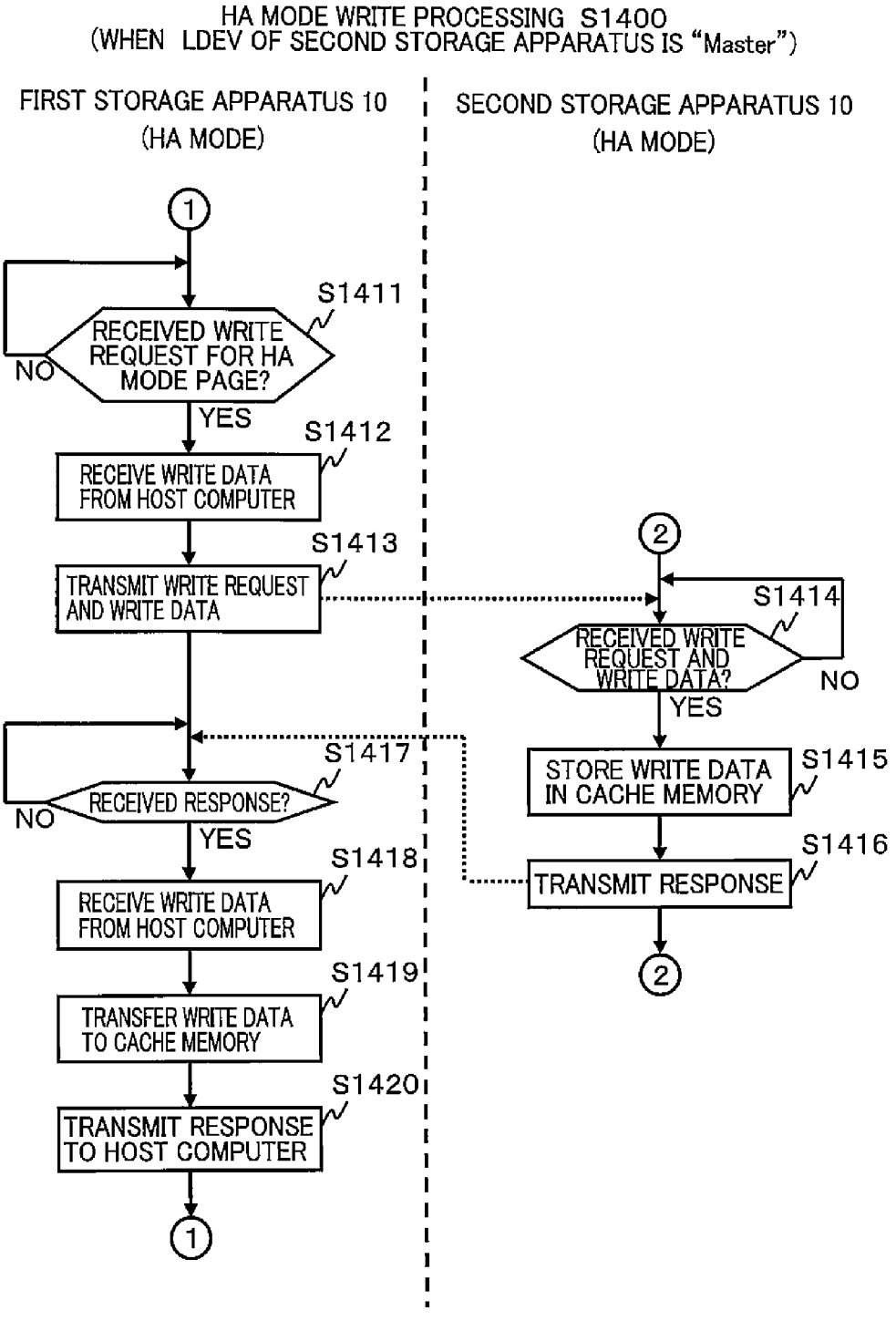
HA MODE WRITE PROCESSING S1400
(WHEN LDEV OF SECOND STORAGE APPARATUS IS "Master")
FIRST STORAGE APPARATUS 10
(HA MODE)
SECOND STORAGE APPARATUS 10
(HA MODE)
1
S1411
RECEIVED WRITE REQUEST FOR HA MODE PAGE?
NO
YES
S1412
RECEIVE WRITE DATA FROM HOST COMPUTER
S1413
TRANSMIT WRITE REQUEST AND WRITE DATA
2
S1414
RECEIVED WRITE REQUEST AND WRITE DATA?
NO
YES
S1415
STORE WRITE DATA IN CACHE MEMORY
S1416
TRANSMIT RESPONSE
2
S1417
RECEIVED RESPONSE?
NO
YES
S1418
RECEIVE WRITE DATA FROM HOST COMPUTER
S1419
TRANSFER WRITE DATA TO CACHE MEMORY
S1420
TRANSMIT RESPONSE TO HOST COMPUTER
1

FIG. 14

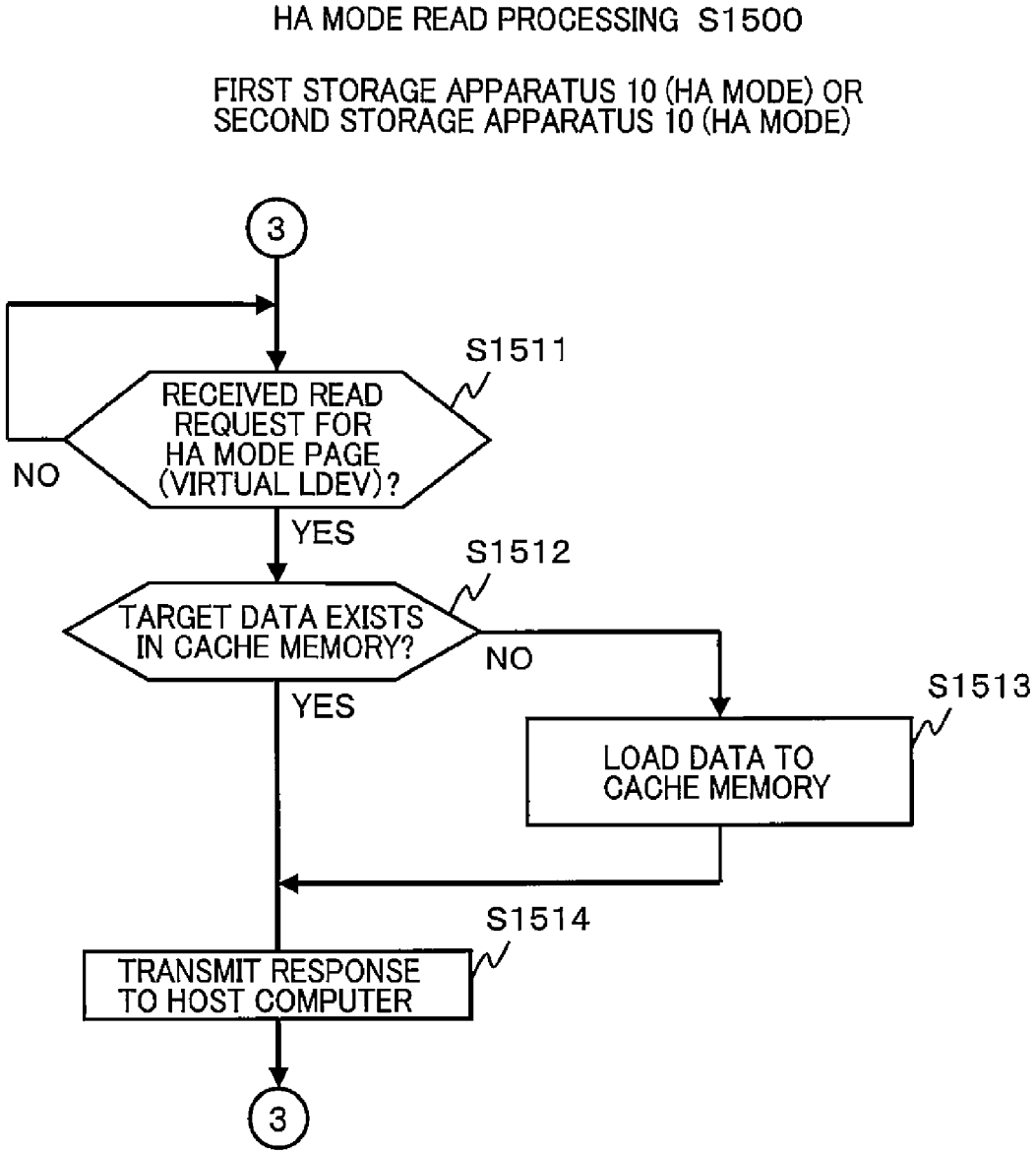
HA MODE READ PROCESSING S1500
FIRST STORAGE APPARATUS 10 (HA MODE) OR SECOND STORAGE APPARATUS 10 (HA MODE)
3
S1511
RECEIVED READ REQUEST FOR HA MODE PAGE (VIRTUAL LDEV)?
NO
YES
S1512
TARGET DATA EXISTS IN CACHE MEMORY?
NO
YES
S1513
LOAD DATA TO CACHE MEMORY
S1514
TRANSMIT RESPONSE TO HOST COMPUTER
3

FIG. 15

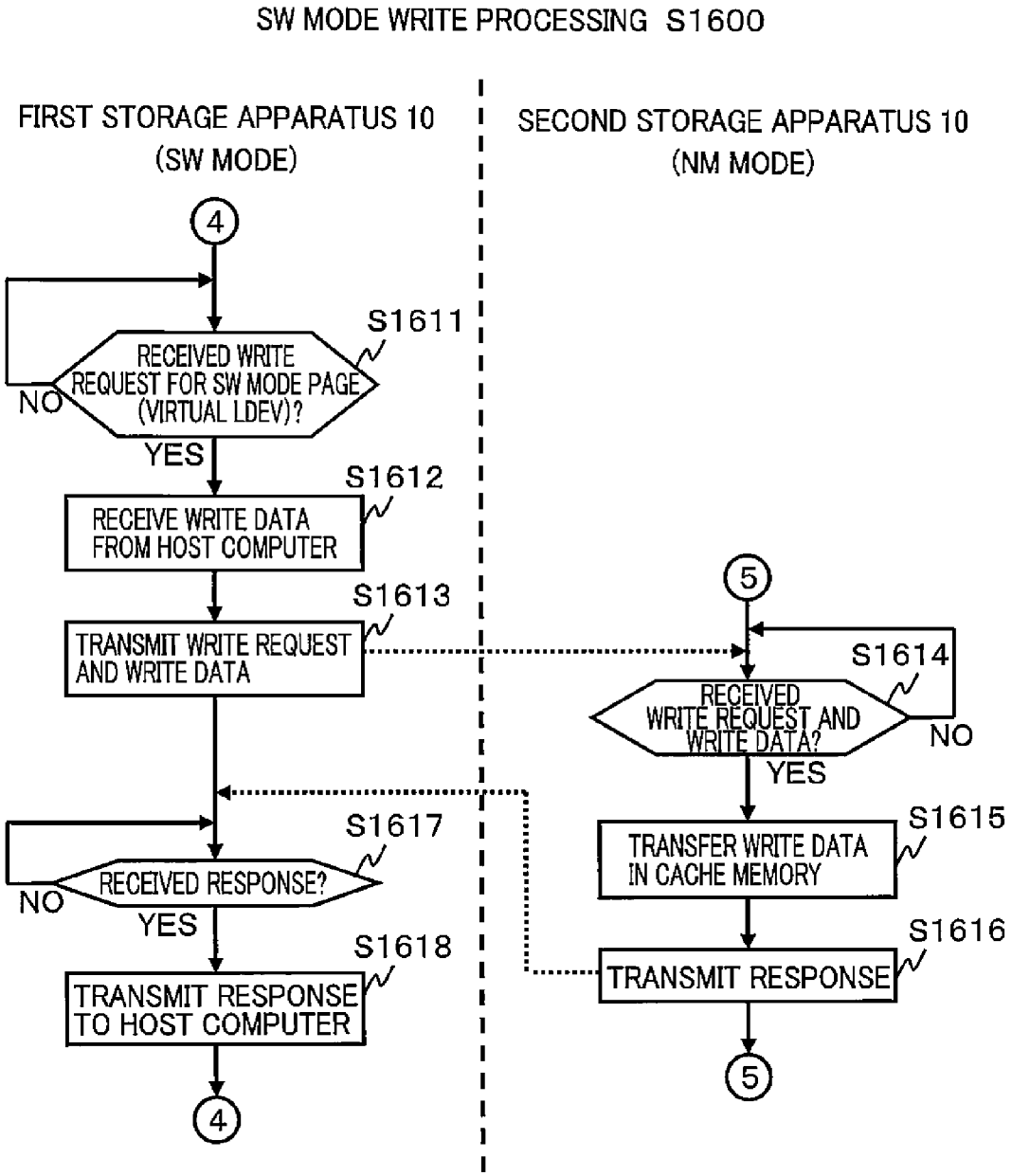
SW MODE WRITE PROCESSING S1600
FIRST STORAGE APPARATUS 10
(SW MODE)
SECOND STORAGE APPARATUS 10
(NM MODE)
4
S1611
RECEIVED WRITE REQUEST FOR SW MODE PAGE (VIRTUAL LDEV)?
NO
YES
S1612
RECEIVE WRITE DATA FROM HOST COMPUTER
S1613
TRANSMIT WRITE REQUEST AND WRITE DATA
5
S1614
RECEIVED WRITE REQUEST AND WRITE DATA?
NO
YES
S1615
TRANSFER WRITE DATA IN CACHE MEMORY
S1616
TRANSMIT RESPONSE
5
S1617
RECEIVED RESPONSE?
NO
YES
S1618
TRANSMIT RESPONSE TO HOST COMPUTER
4

FIG. 16

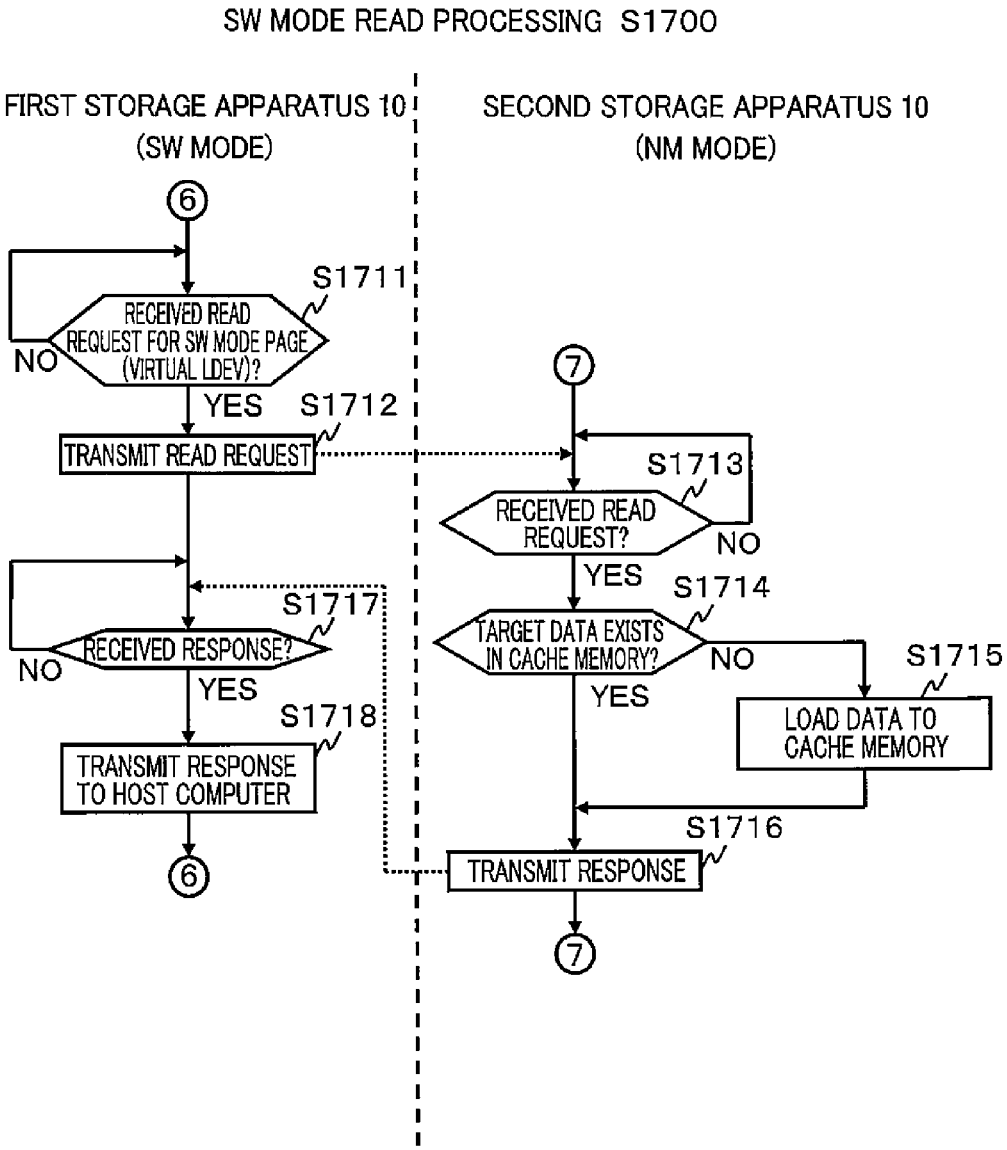
SW MODE READ PROCESSING S1700
FIRST STORAGE APPARATUS 10
(SW MODE)
SECOND STORAGE APPARATUS 10
(NM MODE)
6
S1711
RECEIVED READ REQUEST FOR SW MODE PAGE (VIRTUAL LDEV)?
NO
YES
S1712
TRANSMIT READ REQUEST
7
S1713
RECEIVED READ REQUEST?
NO
YES
S1714
TARGET DATA EXISTS IN CACHE MEMORY?
NO
S1715
LOAD DATA TO CACHE MEMORY
YES
S1716
TRANSMIT RESPONSE
7
S1717
RECEIVED RESPONSE?
NO
YES
S1718
TRANSMIT RESPONSE TO HOST COMPUTER
6

FIG. 17

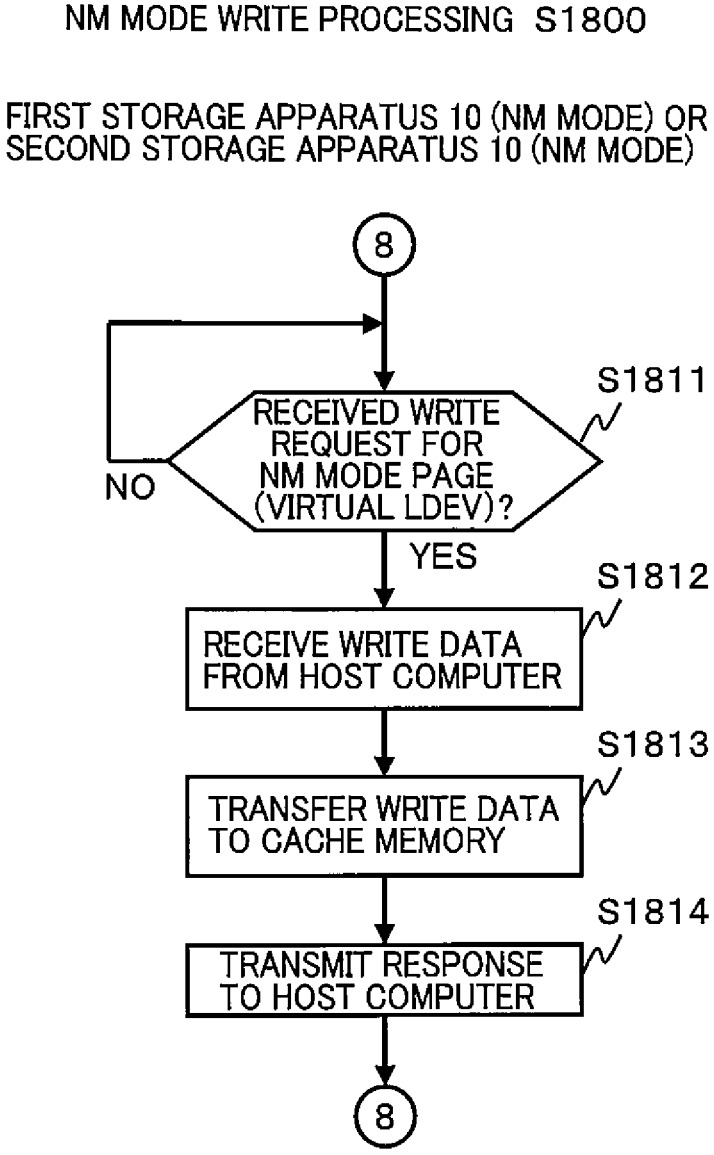
NM MODE WRITE PROCESSING S1800
FIRST STORAGE APPARATUS 10 (NM MODE) OR SECOND STORAGE APPARATUS 10 (NM MODE)
8
S1811
RECEIVED WRITE REQUEST FOR NM MODE PAGE (VIRTUAL LDEV)?
NO
YES
S1812
RECEIVE WRITE DATA FROM HOST COMPUTER
S1813
TRANSFER WRITE DATA TO CACHE MEMORY
S1814
TRANSMIT RESPONSE TO HOST COMPUTER
8

FIG. 18

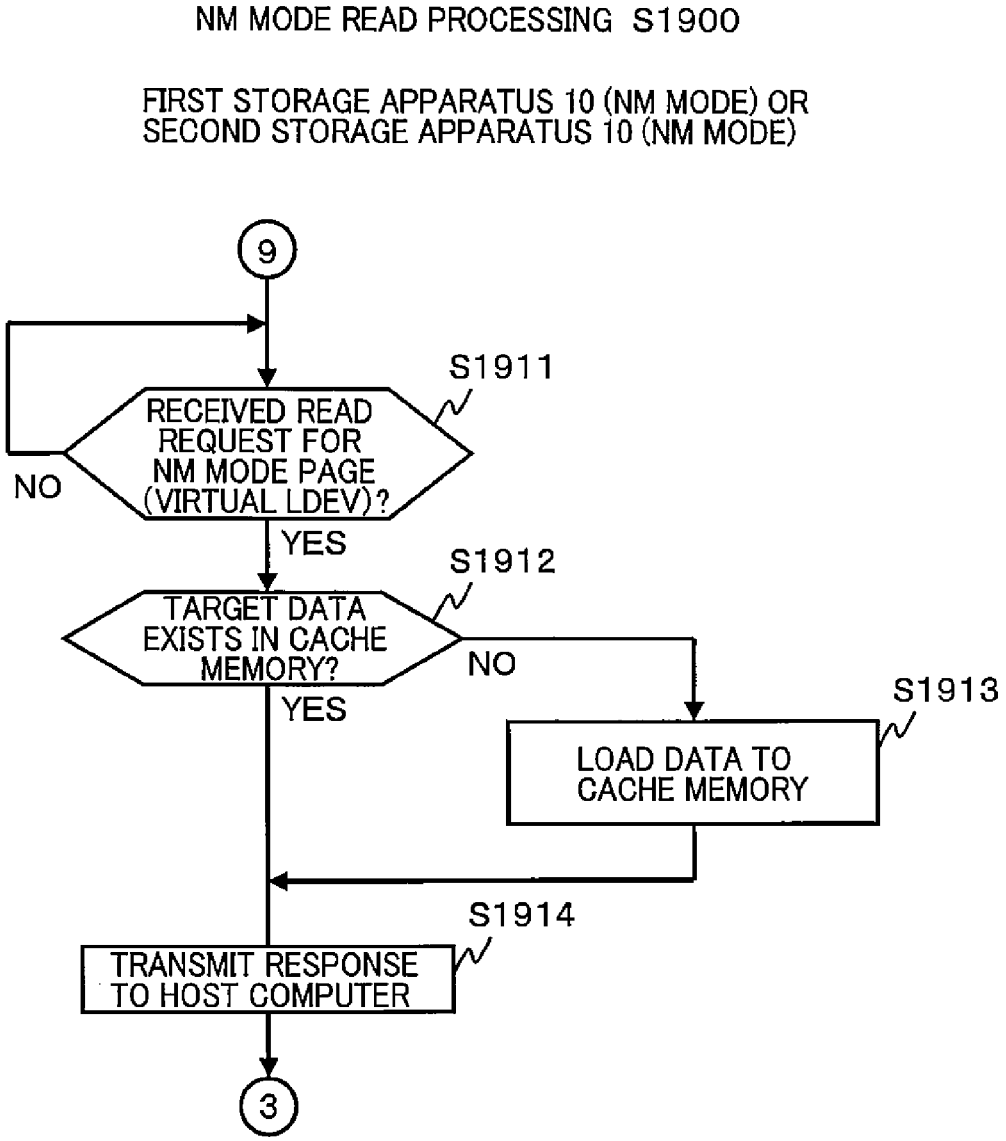
NM MODE READ PROCESSING S1900
FIRST STORAGE APPARATUS 10 (NM MODE) OR SECOND STORAGE APPARATUS 10 (NM MODE)
9
S1911
RECEIVED READ REQUEST FOR NM MODE PAGE (VIRTUAL LDEV)?
NO
YES
S1912
TARGET DATA EXISTS IN CACHE MEMORY?
NO
YES
S1913
LOAD DATA TO CACHE MEMORY
S1914
TRANSMIT RESPONSE TO HOST COMPUTER
3

FIG. 19

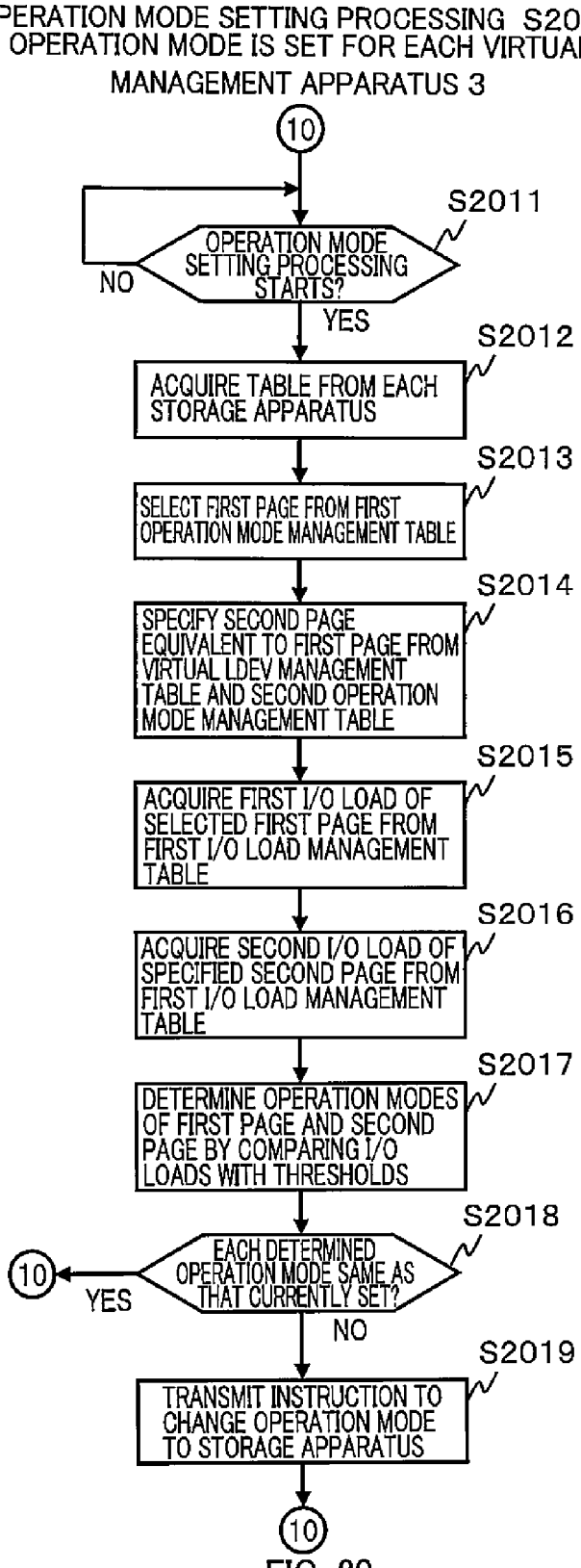
OPERATION MODE SETTING PROCESSING S2000
(WHEN OPERATION MODE IS SET FOR EACH VIRTUAL LDEV)
MANAGEMENT APPARATUS 3
10
S2011
OPERATION MODE SETTING PROCESSING STARTS?
NO
YES
S2012
ACQUIRE TABLE FROM EACH STORAGE APPARATUS
S2013
SELECT FIRST PAGE FROM FIRST OPERATION MODE MANAGEMENT TABLE
S2014
SPECIFY SECOND PAGE EQUIVALENT TO FIRST PAGE FROM VIRTUAL LDEV MANAGEMENT TABLE AND SECOND OPERATION MODE MANAGEMENT TABLE
S2015
ACQUIRE FIRST I/O LOAD OF SELECTED FIRST PAGE FROM FIRST I/O LOAD MANAGEMENT TABLE
S2016
ACQUIRE SECOND I/O LOAD OF SPECIFIED SECOND PAGE FROM FIRST I/O LOAD MANAGEMENT TABLE
S2017
DETERMINE OPERATION MODES OF FIRST PAGE AND SECOND PAGE BY COMPARING I/O LOADS WITH THRESHOLDS
S2018
EACH DETERMINED OPERATION MODE SAME AS THAT CURRENTLY SET?
10
YES
NO
S2019
TRANSMIT INSTRUCTION TO CHANGE OPERATION MODE TO STORAGE APPARATUS
10

FIG. 20

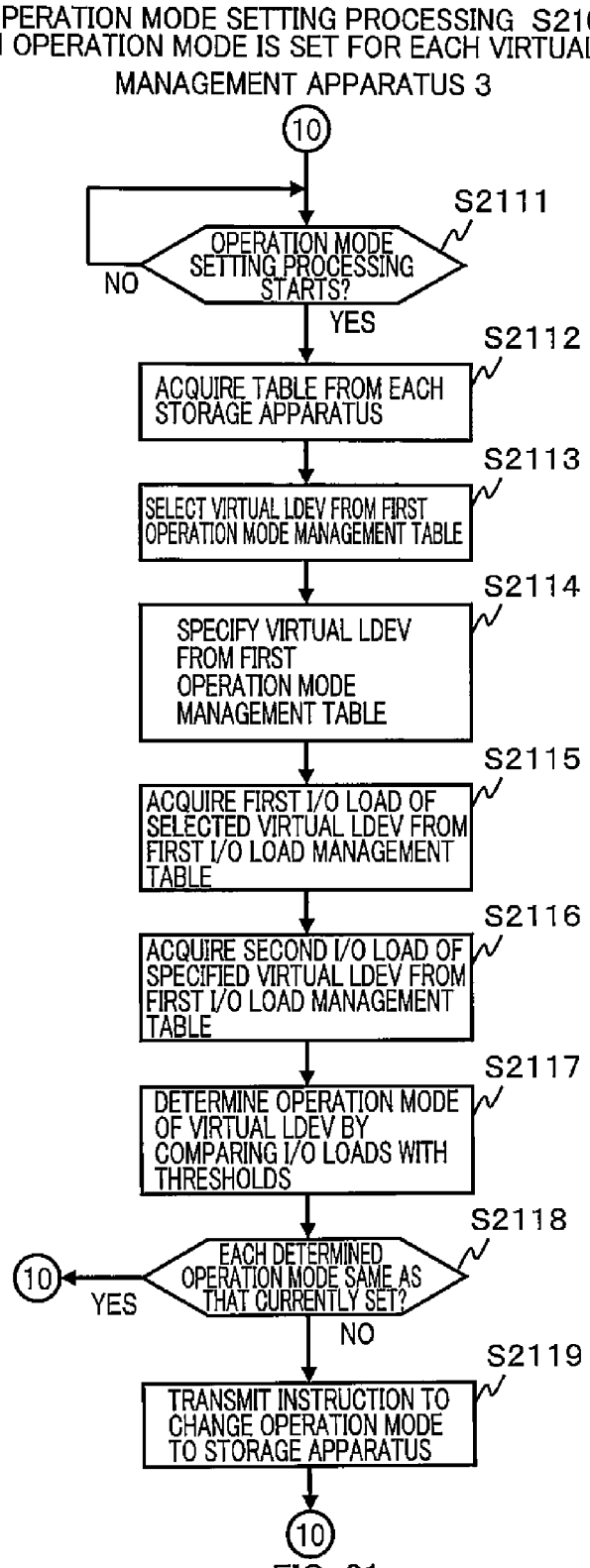
OPERATION MODE SETTING PROCESSING S2100
(WHEN OPERATION MODE IS SET FOR EACH VIRTUAL LDEV)
MANAGEMENT APPARATUS 3
10
S2111
OPERATION MODE SETTING PROCESSING STARTS?
NO
YES
S2112
ACQUIRE TABLE FROM EACH STORAGE APPARATUS
S2113
SELECT VIRTUAL LDEV FROM FIRST OPERATION MODE MANAGEMENT TABLE
S2114
SPECIFY VIRTUAL LDEV FROM FIRST OPERATION MODE MANAGEMENT TABLE
S2115
ACQUIRE FIRST I/O LOAD OF SELECTED VIRTUAL LDEV FROM FIRST I/O LOAD MANAGEMENT TABLE
S2116
ACQUIRE SECOND I/O LOAD OF SPECIFIED VIRTUAL LDEV FROM FIRST I/O LOAD MANAGEMENT TABLE
S2117
DETERMINE OPERATION MODE OF VIRTUAL LDEV BY COMPARING I/O LOADS WITH THRESHOLDS
S2118
EACH DETERMINED OPERATION MODE SAME AS THAT CURRENTLY SET?
10
YES
NO
S2119
TRANSMIT INSTRUCTION TO CHANGE OPERATION MODE TO STORAGE APPARATUS
10

FIG. 21

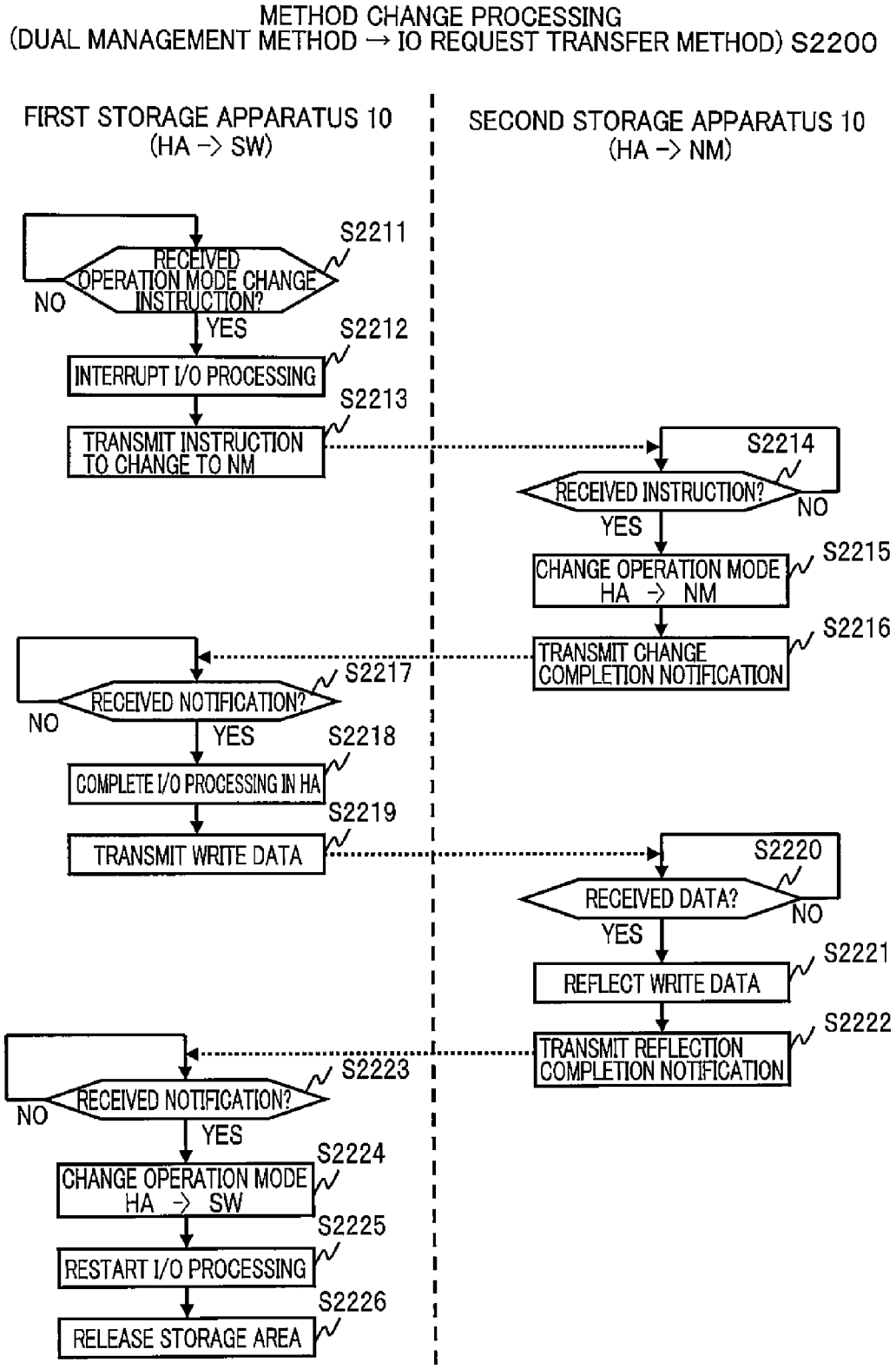
METHOD CHANGE PROCESSING
(DUAL MANAGEMENT METHOD → IO REQUEST TRANSFER METHOD) S2200
FIRST STORAGE APPARATUS 10
(HA -> SW)
SECOND STORAGE APPARATUS 10
(HA -> NM)
S2211
RECEIVED OPERATION MODE CHANGE INSTRUCTION?
NO
YES
S2212
INTERRUPT I/O PROCESSING
S2213
TRANSMIT INSTRUCTION TO CHANGE TO NM
S2214
RECEIVED INSTRUCTION?
NO
YES
S2215
CHANGE OPERATION MODE HA -> NM
S2216
TRANSMIT CHANGE COMPLETION NOTIFICATION
S2217
RECEIVED NOTIFICATION?
NO
YES
S2218
COMPLETE I/O PROCESSING IN HA
S2219
TRANSMIT WRITE DATA
S2220
RECEIVED DATA?
NO
YES
S2221
REFLECT WRITE DATA
S2222
TRANSMIT REFLECTION COMPLETION NOTIFICATION
S2223
RECEIVED NOTIFICATION?
NO
YES
S2224
CHANGE OPERATION MODE HA -> SW
S2225
RESTART I/O PROCESSING
S2226
RELEASE STORAGE AREA

FIG. 22

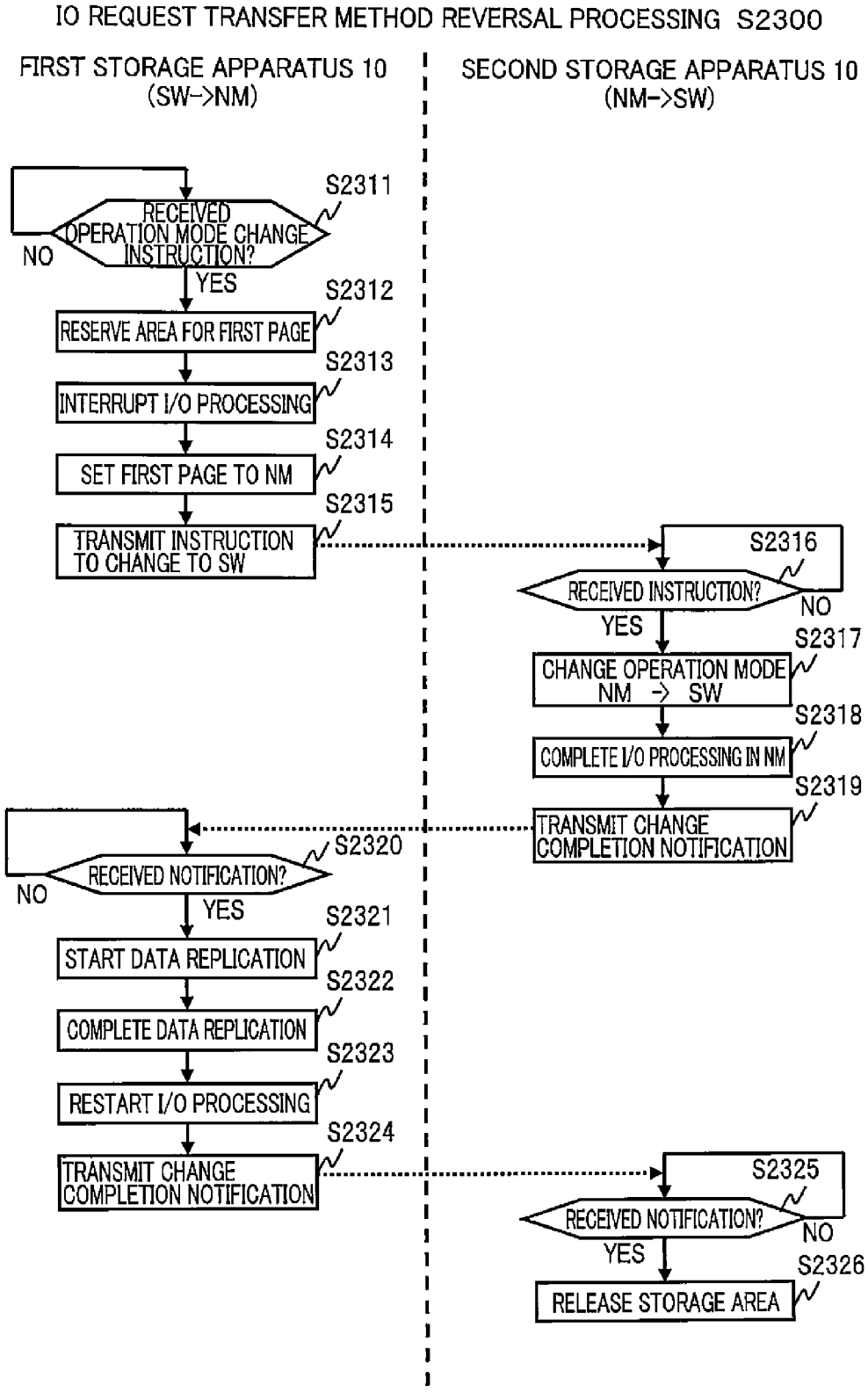
IO REQUEST TRANSFER METHOD REVERSAL PROCESSING S2300
FIRST STORAGE APPARATUS 10 (SW->NM)
SECOND STORAGE APPARATUS 10 (NM->SW)
S2311
RECEIVED OPERATION MODE CHANGE INSTRUCTION?
NO
YES
S2312
RESERVE AREA FOR FIRST PAGE
S2313
INTERRUPT I/O PROCESSING
S2314
SET FIRST PAGE TO NM
S2315
TRANSMIT INSTRUCTION TO CHANGE TO SW
S2316
RECEIVED INSTRUCTION?
NO
YES
S2317
CHANGE OPERATION MODE NM -> SW
S2318
COMPLETE I/O PROCESSING IN NM
S2319
TRANSMIT CHANGE COMPLETION NOTIFICATION
S2320
RECEIVED NOTIFICATION?
NO
YES
S2321
START DATA REPLICATION
S2322
COMPLETE DATA REPLICATION
S2323
RESTART I/O PROCESSING
S2324
TRANSMIT CHANGE COMPLETION NOTIFICATION
S2325
RECEIVED NOTIFICATION?
NO
YES
S2326
RELEASE STORAGE AREA

FIG. 23

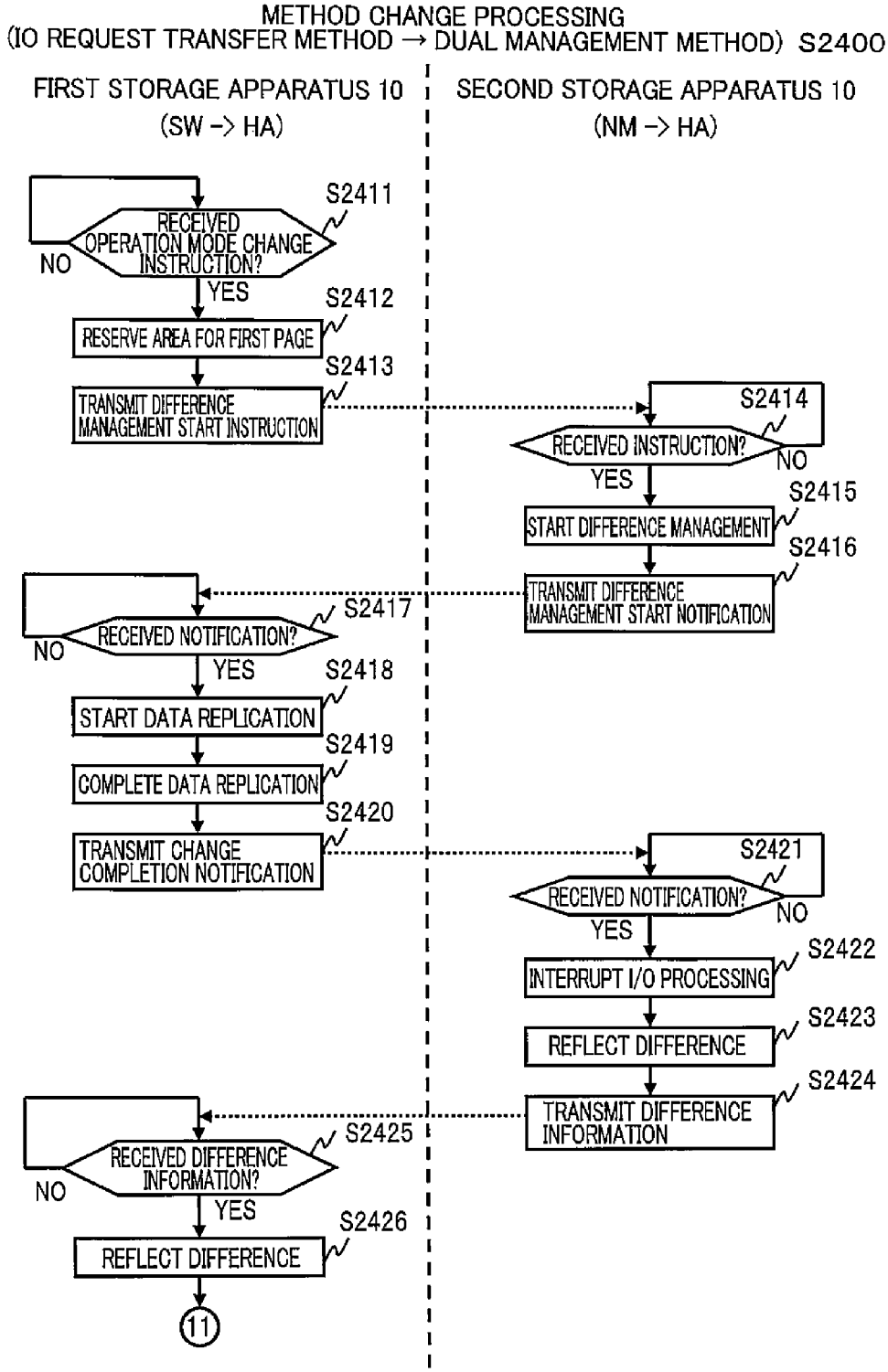
METHOD CHANGE PROCESSING
(IO REQUEST TRANSFER METHOD → DUAL MANAGEMENT METHOD) S2400
FIRST STORAGE APPARATUS 10
(SW -> HA)
SECOND STORAGE APPARATUS 10
(NM -> HA)
S2411
RECEIVED OPERATION MODE CHANGE INSTRUCTION?
NO
YES
S2412
RESERVE AREA FOR FIRST PAGE
S2413
TRANSMIT DIFFERENCE MANAGEMENT START INSTRUCTION
S2414
RECEIVED INSTRUCTION?
NO
YES
S2415
START DIFFERENCE MANAGEMENT
S2416
TRANSMIT DIFFERENCE MANAGEMENT START NOTIFICATION
S2417
RECEIVED NOTIFICATION?
NO
YES
S2418
START DATA REPLICATION
S2419
COMPLETE DATA REPLICATION
S2420
TRANSMIT CHANGE COMPLETION NOTIFICATION
S2421
RECEIVED NOTIFICATION?
NO
YES
S2422
INTERRUPT I/O PROCESSING
S2423
REFLECT DIFFERENCE
S2424
TRANSMIT DIFFERENCE INFORMATION
S2425
RECEIVED DIFFERENCE INFORMATION?
NO
YES
S2426
REFLECT DIFFERENCE
11

FIG. 24

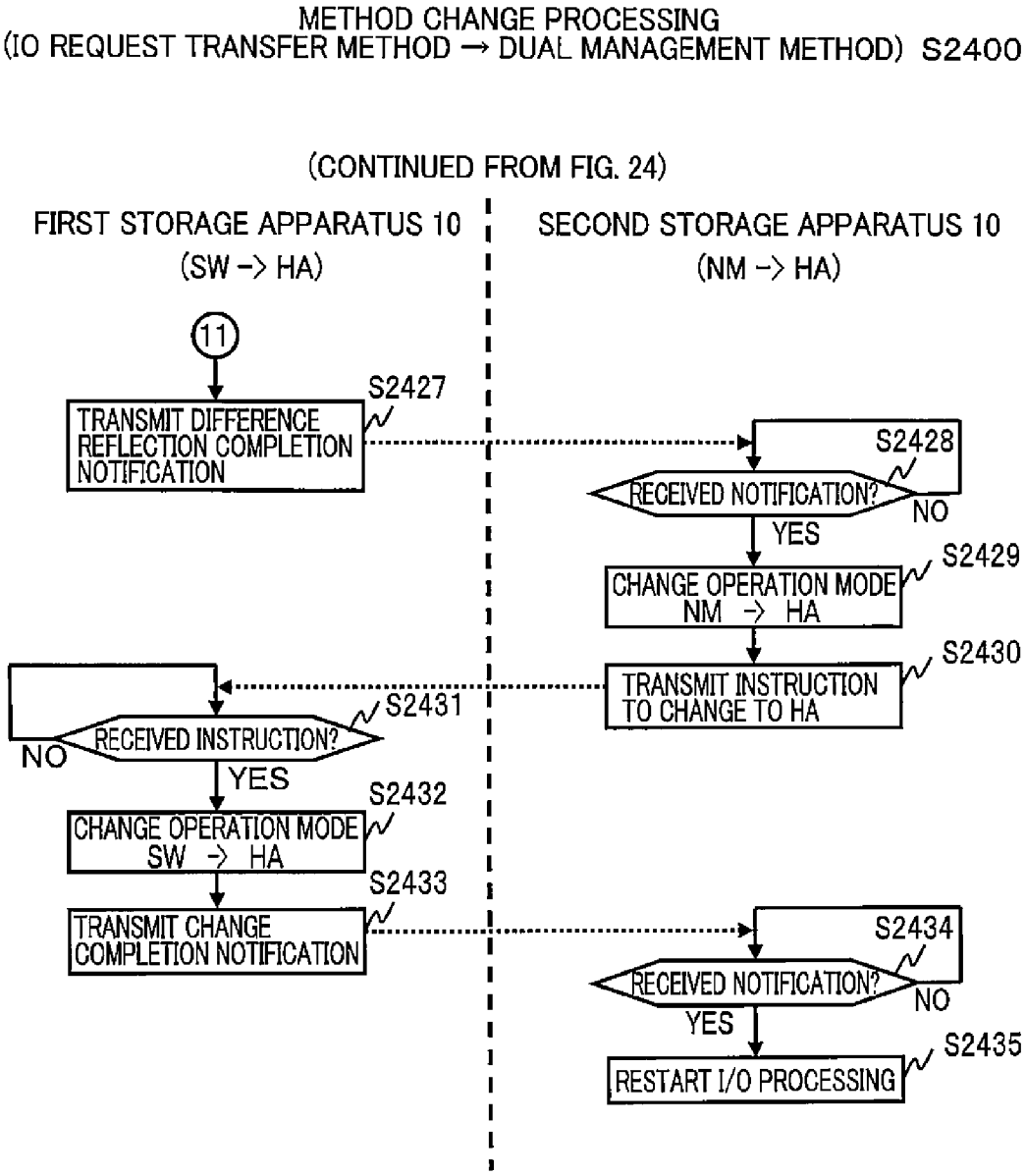
METHOD CHANGE PROCESSING
(IO REQUEST TRANSFER METHOD → DUAL MANAGEMENT METHOD) S2400
(CONTINUED FROM FIG. 24)
FIRST STORAGE APPARATUS 10
(SW -> HA)
SECOND STORAGE APPARATUS 10
(NM -> HA)
11
S2427
TRANSMIT DIFFERENCE REFLECTION COMPLETION NOTIFICATION
S2428
RECEIVED NOTIFICATION?
NO
YES
S2429
CHANGE OPERATION MODE NM -> HA
S2430
TRANSMIT INSTRUCTION TO CHANGE TO HA
S2431
RECEIVED INSTRUCTION?
NO
YES
S2432
CHANGE OPERATION MODE SW -> HA
S2433
TRANSMIT CHANGE COMPLETION NOTIFICATION
S2434
RECEIVED NOTIFICATION?
NO
YES
S2435
RESTART I/O PROCESSING

FIG. 25

STORAGE SYSTEM AND METHOD OF CONTROLLING THE SAME

TECHNICAL FIELD

The present invention relates to a storage system and a method of controlling the storage system.

BACKGROUND ART

PTL 1 discloses an information system including a virtual storage apparatus 1000L and a virtual storage apparatus 1000R. The virtual storage apparatus 1000L provides a volume 3000LA to which the storage areas of its own HDDs 1030 are allocated, while the virtual storage apparatus 1000R provides a volume 3000RA to which the storage areas of HDDs 1030 in the virtual storage device itself are allocated. A same identifier is assigned to the volume 3000LA and the volume 3000RA. When receiving a write request for the volume 3000LA from a host, the virtual storage apparatus 1000L returns a response indicating that IO has succeeded to the host after confirming that both writing to the volume 3000LA and writing to the volume 3000RA of the virtual storage apparatus 1000R have been completed.

CITATION LIST

Patent Literature

PTL 1: JP-A 2009-266120

SUMMARY OF INVENTION

Technical Problem

Here, there is a configuration in which a storage apparatus A provides computers with a virtual volume A corresponding to a physical volume A and a storage apparatus B provides the computers with a virtual volume B corresponding to a physical volume B and having the same identifier as that of the virtual volume A. In a case where the storage apparatus A receives a write request for the virtual volume A from the computer in the above configuration, it is necessary to issue to the computer a completion report for the write request after storing data in both of the physical volume A and the physical volume B of the storage apparatus B in order to allow the plurality of computers to access any of the storage apparatuses.

However, in this case, if a high IO load is applied to only one of the storage apparatus A and the storage apparatus B, the storage apparatus with the high IO load has to transmit write data to the other storage apparatus every time a write request is received, which in turn poses a problem of how to secure IO performance for the computers. Further, when the IO load is biased to either one of the storage apparatuses, the other storage apparatus receives a small amount of read requests so that even if the other storage apparatus were to have retained real data, response performance to the read request cannot be improved compared to the case where the other storage apparatus does not retain real data.

The present invention has been made in view of the above-described background and the main objective of the present invention is to provide a storage system and a method of controlling the storage system which are capable of providing an environment for the usage of a virtual volume while securing IO performance and the like.

Solution to Problem

One aspect of the present invention to achieve the objective is a storage system which includes a first storage apparatus including a first logical volume associated with a virtual volume, and providing the virtual volume, and a second storage apparatus being coupled to the first storage apparatus, having a second logical volume associated with the virtual volume, and providing the virtual volume, wherein the first storage apparatus when receiving a first write request for the virtual volume, is capable of performing a processing for the first write request by one of a first write processing method by which a processing of storing write data relating to the first write request in the first logical volume is executed as well as the first write request is transferred to the second storage apparatus to store the write data in the second logical volume in the second storage apparatus, and a second write processing method by which the first write request is transferred to the second storage apparatus to store the write data in the second logical volume in the second storage apparatus without executing the processing of storing the write data in the first logical volume, and the first storage apparatus performs a processing for the first write request by selecting either the first write processing method or the second write processing method according to a first IO load for a predetermined area of the virtual volume in the first storage apparatus, and a second IO load for the predetermined area of the virtual volume in the second storage apparatus.

Other problems and solutions to the problems which are disclosed in the present application will become apparent from the description of embodiments and the drawings.

Advantageous Effects of Invention

According to the present invention, there can be provided an environment for the usage of a virtual volume while securing IO performance and the like.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a drawing illustrating a schematic configuration of an information processing system **1**.

FIG. **2** is a drawing showing main programs and data which are stored in main components of the information processing system **1**.

FIG. **3** is an example of an LDEV management table **121** which is stored in a first storage apparatus **10**.

FIG. **4** is an example of the LDEV management table **121** which is stored in a second storage apparatus **10**.

FIG. **5** is an example of a virtual LDEV management table **122** which is stored in the first storage apparatus **10**.

FIG. **6** is an example of a virtual LDEV management table **122** which is stored in the second storage apparatus **10**.

FIG. **7** is an example of an operation mode management table **123** which is stored in the first storage apparatus **10**.

FIG. **8** is an example of the operation mode management table **123** which is stored in the second storage apparatus **10**.

FIG. **9** is an example of an IO load management table **124** which is stored in the first storage apparatus **10**.

FIG. **10** is an example of the IO load management table **124** which is stored in the second storage apparatus **10**.

FIG. **11** is a drawing schematically illustrating an operation of the storage system when dual management method is performed.

FIG. **12** is a drawing schematically illustrating an operation of the storage system when IO request transfer method is performed.

FIG. **13** is a drawing schematically illustrating an operation of the storage system when a normal method is performed.

FIG. **14** is a flowchart illustrating HA mode write processing S**1400**.

FIG. **15** is a flowchart illustrating HA mode read processing S**1500**.

FIG. **16** is a flowchart illustrating SW mode write processing S**1600**.

FIG. **17** is a flowchart illustrating SW mode read processing S**1700**.

FIG. **18** is a flowchart illustrating NM mode write processing S**1800**.

FIG. **19** is a flowchart illustrating NM mode read processing S**1900**.

FIG. **20** is a flowchart illustrating operation mode setting processing S**2000**.

FIG. **21** is a flowchart illustrating operation mode setting processing S**2100**.

FIG. **22** is a flowchart illustrating method change processing (dual->IO request transfer) S**2200**.

FIG. **23** is a flowchart illustrating IO request transfer method reverse processing S**2300**.

FIG. **24** is a flowchart illustrating method change processing (IO request transfer method->dual management method) S**2400**.

FIG. **25** is a flowchart illustrating method change processing (IO request transfer method->dual management method) S**2400** (continued from FIG. **24**).

DESCRIPTION OF EMBODIMENTS

FIG. **1** shows a schematic configuration of an information processing system **1** which is described as an embodiment. As shown in FIG. **1**, the information processing system **1** includes a storage system which is configured of two storage apparatuses **10** (a first storage apparatus **10**, a second storage apparatus **10**), at least one host computer **2** which accesses to the first storage apparatus **10** and the second storage apparatus **10**, a management apparatus **3** which monitors, controls, sets and the like each component in the information processing system **1**, a first communication network **5**, and a second communication network **6**. In the following description, when matters common to the first storage apparatus **10** and the second storage apparatus **10** are described, they may be collectively referred to as the "storage apparatus **10**".

The host computer **2** is, for example, an information processing apparatus which is used for providing bank's automated teller services, Internet web page browsing services and the like, and is configured of hardware such as a personal computer, an office computer, a mainframe and the like.

The first communication network **5** is used for transmitting an IO request which is issued from the host computer **2** to the storage apparatus **10**, and responding to the IO request from the storage apparatus **10** to the host computer **2**. The IO request is a data write request (hereinafter, referred to as a wire request), a data read request (hereinafter, referred to as a read request), or the like.

The first communication network **5** is, for example, SAN (Storage Area Network), LAN (Local Area Network), WAN (Wide Area Network), the Internet or the like, and is configured with a network switch such as a switching hub, a router or the like. Communications via the first communication network **5** are performed using a communication protocol such as TCP/IP, FCoE (Fibre Channel over Ethernet), iSCSI (Internet Small Computer System Interface) and the like.

The host computer **2** includes a central processing unit **21**, a storage device **22**, a first communication device **23**, and a second communication device **24**. The central processing unit **21** is configured with, for example, a CPU or MPU. The storage device **22** is a volatile or non-volatile memory (RAM, ROM, NVRAM (Non Volatile RAM)), a hard disk drive, SSD (Solid State Drive), or the like. The first communication device **23** is, for example, an HBA, and communicates with other devices via the first communication network **5**. The second communication device **24** is, for example, a NIC, and communicates with other devices via the second communication network **6**. The host computer **2** may include an input device (such as a keyboard, a mouse, and a touch panel) and an output device (such as a liquid crystal monitor and a printer).

The management apparatus **3** provides the administrator and the like of the information processing system **1** with a user interface (such as GUI (Graphical User Interface) and CLI (Command Line Interface)) which is used for monitoring, controlling, and setting the information processing system **1**.

The management apparatus **3** performs transmits information (such as collects information for monitoring, sends a control command, and sends/receives setting information) as needed between the host computer **2** and the storage apparatus **10** via the second communication network **6**.

The second communication network **6** is, for example, LAN, WAN, the Internet, a public telecommunication network, a lease line, or the like, and is configured with a network switch such as a switching hub or a router. Communications via the second communication network **6** are performed using a communication protocol such as TCP/IP.

The management apparatus **3** includes a central processing unit **31**, a storage device **32**, a first communication device **33**, and a second communication device **34**. The central processing unit **31** is configured with, for example, a CPU and an MPU. The storage device **32** is a volatile or a non-volatile memory **22** (RAM, ROM, NVRAM), a hard disk drive, SSD, or the like. The first communication device **33** is, for example, an HBA, and communicates with other devices via the first communication network **5**. The second communication device **34** is, for example, a NIC and communicates with other devices via the second communication network **6**.

The storage apparatus **10** is a disk array apparatus for providing the host computer **2** with a data storage area. The storage apparatus **10** includes at least one communication control unit **11**, a data transfer device **12**, at least one drive control unit **13**, a cache memory **14**, a shared memory **15**, a storage drive **17**, a maintenance device **18** (also referred to as SVP (Service Processor)), and a storage controller **19**. The storage controller **19** (also simply called controller) includes at least one communication control unit **11**, a data transfer device **12**, at least one drive control unit **13**, a cache memory **14**, a shared memory **15**, and a maintenance device **18**.

The communication control unit **11** (also referred to as a channel control unit), the drive control unit **13**, the cache memory **14**, and the shared memory **15** are communicatively coupled with one another via communication means such as a crossbar switch, PCI bus (PCI: Peripheral Component Interconnect), or PCI-Express bus. The storage drive **17** may be accommodated in a chassis different from the other components configuring the storage apparatus **10**.

The communication control unit **11** communicates with other devices (including other storage apparatuses **10**) via the first communication network **6**. The communication control unit **11** includes a central processing unit (such as a CPU, an MPU), a storage device (such as a semiconductor memory), and a communication device (such as an HBA (Host Bus Adaptor), a NIC (Network Interface card)). The communica-

tion control unit **11**, for example, communicates with other devices which is performed according to the communication protocol or performs processing relating to the IO request received from the host computer **2**.

The drive control unit **13** communicates with the storage drive **17**, and writes data into the storage drive **17** or reads the data from the storage drive **17**. The drive control unit **13** includes a central processing unit (such as a CPU, MPU), a storage device (such as a semiconductor memory), and a communication device (such as HBA, NIC, or SCSI interface).

The data transfer device **12** mediates data transfer which is performed among the communication control unit **11**, the drive control unit **13**, and the cache memory **14**. The data transfer device **12** includes a device capable of high-speed data transfer (such as DMA (Direct Memory Access), a central processing unit (CPU, MPU)), and a storage device (such as a semiconductor memory). For example, the data transfer device **12** performs data transfer (data read from the storage drive **17**, data to be written into the storage drive **17**) between the communication control unit **11** and the drive control unit **13** via the cache memory **14**, reads the data from the storage drive **17**, the data being stored in the cache memory **14**, or writes the data in the storage drive **17**.

The cache memory **14** temporarily stores, for example, data to be written in the storage drive **17** or data which is read from the storage drive **17** to be transmitted to the host computer **2**. The cache memory **14** is configured with, for example, a RAM capable of writing/reading data at a high speed.

The shared memory **15** stores programs and data which are utilized by, for example, the communication control unit **11**, the data transfer device **12**, or the drive control unit **13**. The shared memory **15** is configured using, for example, a RAM, a ROM, or an NVRAM.

The maintenance device **18** monitors, controls, and sets each component included in the storage apparatus **10**. The maintenance device **18** is an information processing apparatus (for example, a personal computer) including a central processing unit, a memory, an auxiliary storage device, an input device, a display device, a communication circuit and the like.

The maintenance device **18** acquires information (such as configuration information, various pieces of setting information, operation information) from the storage apparatus **10** by communicating with the components included in the storage apparatus **10** via communication means such as a LAN. Also, the maintenance device **18** communicates with the management apparatus **3** via the second communication network **6** and transmits information between the management apparatus **3**.

The storage driver **17** is, for example, a hard disk drive (such as SAS (Serial Attached SCSI), SATA (Serial ATA), FC (Fibre Channel), PATA (Parallel ATA), or SCSI (Small Computer System Interface)) or a semiconductor storage device (SDD).

The storage apparatus **10** configures a logical storage area (hereinafter referred to as LEDV (Logical Device)) which is provided by controlling the storage drive **17** with a RAID (Redundant Array of Inexpensive (or Independent) Disks) method (for example, RAID0 to 6). This logical storage area is implemented using a storage area of, for example, a RAID group (also referred to as a parity group).

A unique identifier (LDEV-ID) is assigned to LEDV. The host computer **2** transmits to the storage apparatus **10** an IO request in which an LDEV-ID is designated, and then the storage apparatus **10** performs processing for the IO request by targeting the LEDV-ID (or the LDEV-ID corresponding to the identifier relating to the data storage area specified in the IO request)designated in the IO request.

The storage apparatus **10** configures a virtual storage area (hereinafter referred to as a virtual LDEV) associated with the configured LDEV and provides the host computer **2** with the configured virtual LDEV. Similar to the case where the host computer **2** accesses the storage apparatus **10** by targeting the LDEV, the host computer **2** can transmit to the storage apparatus **10** an IO request in which a unique identifier is given to each of the virtual LDEVs (hereinafter referred to as a virtual LDEV-ID) is designated. When receiving the IO request in which the virtual LDEV-ID is designated, the storage apparatus **10** performs processing corresponding to the IO request on the LDEV associated with the designated virtual LDEV.

Also, the first storage apparatus **10** and the second storage apparatus **10** can provide the host computer **2** with virtual LDEVs to which the same virtual LDEV-ID is given as an identifier of the virtual LDEV (hereinafter referred to as a virtual LDEV-ID). In other words, each storage apparatus **10** (the first storage apparatus **10** and the second storage apparatus **10**) can provide the host computer **2** with different LDEV storage areas of the different storage apparatuses **10** to which the same virtual LDEV-ID corresponds as if they were a single storage area.

FIG. **2** shows main programs and main data which are stored in the main components of the information processing system **1**. Note that in the following description, "program" is also denoted as "PG".

The main functions provided by the host computer **2** are implemented by the central processing unit **21** of the host computer **2** reading and executing programs stored in the storage device **22**. Also, the main functions provided by the management apparatus **3** are implemented by the central processing unit **31** of the management apparatus **3** reading and executing programs stored in the storage device **32**. Also, the main functions provided by the storage apparatus **10** are implemented by at least one of the communication control unit **11**, data transfer device **12**, and drive control unit **13** in the storage apparatus **10** reading and executing programs stored in the shared memory **15**. Note that, the program stored in the shared memory **15** may be stored in the storage drive **17**.

As shown in FIG. **2**, the storage device **22** of the host computer **2** stores an application PG **211**, an operating system PG **212**, and a device driver PG **213**.

Among the above, the application PG **211** implements functions relating to, for example, a bank's automated teller services, or Internet web page browsing services.

The operating system PG **212** implements functions relating to process control executed in the host computer **2** (such as process execution management, process scheduling, or management of a storage area to be used by the process), functions relating to a file system, functions relating to file share, or the like.

The device driver PG **213** implements functions relating to control of hardware and peripheral devices included in the host computer **2**.

Here, an IO request to be transmitted from the host computer **2** to the storage apparatus **10** is generated by executing at least one of the application PG **211**, the operating system PG **212**, and the device driver PG **213**.

As shown in FIG. **2**, the storage device **32** of the management apparatus **3** stores an application PG **311**, an operating system PG **312**, and a device driver PG **313** as main programs.

Among the above, the application PG **311** implements functions relating to services relating to management or maintenance of the information processing system **1**.

The operating system PG **312** implements functions relating to process control executed in the management apparatus **3** (such as execution management, scheduling, management of a storage area used by the process, or handling of an interruption request), functions relating to a file system, functions relating to file share, or the like.

The device driver PG **313** implements functions relating to control of hardware and peripheral devices which are included in the management apparatus **3**.

As shown in FIG. **2**, the storage apparatus **10** stores as main programs, an IO request processing PG **111**, an HA mode operation control PG **112**, an SW mode operation control PG **113**, an NM mode operation control PG **114**, an operation mode switch control PG **115**, and an IO load information acquisition PG **116**. These programs are stored in, for example, the share memory **15** of the storage apparatus **10**, a storage device of the communication control unit **11**, a storage device of the drive control unit **13**, a storage device of the data transfer device **12**, or the like.

Among the above, the IO processing PG **111** implements processing (hereinafter referred to as IO processing) in response to the IO request which is received by the storage apparatus **10** from the host computer **2**, so as to implement functions to perform basic operations when a response is returned to the host computer **2** and functions to provide a virtual LDEV to the host computer **2**.

The HA mode operation control PG **112** implements a function to operate the storage apparatus **10** in an "HA mode" (first operation mode) among the operation modes to be described later when the data which is received by the storage apparatus **10** from the host computer **2** is managed by dual management to be described later.

The SW mode operation control PG **113** implements a function to operate the storage apparatus **10** in an "SW mode" (second operation mode) among the operation modes to be described later when the data which is received by the storage apparatus **10** from the host computer **2** is managed by IO request transfer method to be described later.

The NM (Normal) mode operation control PG **114** achieves a function to operate the storage apparatus **10** in an "NM mode" (a third operation mode) among operation modes to be described later when the data which is received by the storage apparatus **10** from the host computer **2** is managed by IO request transfer method or a normal method to be described later.

Note that, with regard to the area of the virtual LDEV managed under the "HA mode" on the first storage apparatus **10** side, the corresponding area of the virtual LDEV on also the second storage apparatus **10** side is managed under the "HA mode". Additionally, with regard to the area of the virtual LDEV managed under the "NM mode" on the first storage apparatus **10** side, the corresponding area of the virtual LDEV on the second storage apparatus **10** side is managed under the "SW mode". Further, with regard to the area of the virtual LDEV managed under the "SW mode" on the first storage apparatus **10** side, the corresponding area of the virtual LDEV on the second storage apparatus **10** side is managed under the "NM mode".

The operation mode switch control PG **115** implements a function relating to switching of the operation modes of the storage apparatus **10**.

The IO load information acquisition PG **116** acquires information (such as access frequency per unit time (the IO request count received from the host computer **2**), hereinafter also referred to as IO load information) relating to an IO load for each page of the virtual LDEV to be described later. The acquired information is used for switching the operation modes to be described later.

As shown in FIG. **2**, the storage apparatus **10** stores an LDEV management table **121**, a virtual LDEV management table **122**, an operation mode management table **123**, and an IO load management table **124** as main data. These tables are stored in, for example, the shared memory **15** of the storage apparatus **10**, a storage device of the communication control unit **11**, a storage device of the drive control unit **13**, a storage device of the data transfer device **12**, or the like.

Among the above, the LDEV management table **121** manages correspondence between the storage drives **17** and LDEVs. FIG. **3** shows an example of the LDEV management table **121** which is stored in the first storage apparatus **10**, while FIG. **4** shows an example of the LDEV management table **121** which is stored in the second storage apparatus **10**.

As shown in these figures, the LDEV management table **121** is configured with at least one record including items of a RAID group ID **311** in which an identifier of a RAID group (hereinafter referred to as RAID-ID) is set and LDEV-ID **312** in which an identifier of LDEV (hereinafter referred to as LDEV-ID) configured using a RAID group specified by the RAID group ID is set. Note that in these figures, values in brackets attached to RAID group ID **311** is an identifier (hereinafter referred to as drive ID) of the storage drive **17** constituting that RAID group.

The virtual LDEV management table **122** manages correspondences among the virtual LDEV, the LDEV of the first storage apparatus **10**, and the LDEV of the second storage device **10**. FIG. **5** shows an example of the virtual LDEV management table **122** which is stored in the first storage apparatus **10**, while FIG. **6** shows an example of the virtual LDEV management table **122** which is stored in the second storage apparatus **10**.

As shown in these figures, the virtual LDEV management table **122** is configured of at least one record including items of a virtual production number **411**, a virtual LDEV **412**, a first LDEV **413**, a first LDEV attribute **414**, a second LDEV **415**, a second LDEV attribute **416**, and path information **417**.

Among the items, in the virtual production number **411**, a virtual production number of the virtual LDEV (a production number which is virtually given) is set. Note that a unique production number (hereinafter referred to as a real production number) is assigned to each storage apparatus **10** when, for example, a storage apparatus **10** is manufactured. Each storage apparatus **10** itself stores a real production number which is assigned to the apparatus, and the host computer **2** designates the storage apparatus **10** in a communication destination with the real production number.

In the virtual LDEV, an identifier of a virtual LDEV (virtual LDEV-ID) is set.

In the first virtual LDEV **413**, there is set the LDEV-ID of the LDEV of the first storage apparatus **10** which is associated with the virtual LDEV is set. In the first attribute **414**, there is set information ("Master" or "Slave") indicating an attribute to be described later which is assigned to the LDEV.

In the second LDEV **415**, there is set the LDEV-ID of the LDEV of the second storage apparatus **10** which is associated with the virtual LDEV. In the second attribute **416**, there is set information ("Master" or "Slave") indicating an attribute to be described later which is assigned to the LDEV.

In the path information **417**, there is set information (hereinafter referred to as path information) specifying the path to be used when the first storage apparatus **10** and the second storage apparatus **10** communicate with each other via the first communication network **5**. Path information is expressed

in combination of, for example, an identifier (for example, WWN (World Wide Name)) of a port of the communication control unit **11** to be the transmission source (an initiator) and an identifier (for example, WWN) of a port of the communication control unit **11** to be the transmission destination (a target).

The operation mode management table **123** manages operation modes to be described later, which are respectively set for each management unit (hereinafter referred to as a page) of the storage area of the virtual LDEV. FIG. **7** shows an example of the operation mode management table **123** which is stored in the first storage apparatus **10**, while FIG. **8** shows an example of the operation mode management table **123** which is stored in the second storage apparatus **10**.

As shown in these figures, the operation mode management table **123** is configured with the following items of a virtual LDEV **511**, a page **512**, an operation mode **513**, and an operation mode change permission **514**.

Among the above, an identifier of a virtual LDEV (virtual LDEV-ID) is set in the virtual LDEV **511**.

In the page **512**, there is set an identifier assigned to each page (hereinafter referred to as a page ID) is set. Note that an address showing a storage area of the virtual LDEV corresponding to the page is set in the brackets attached to the page ID.

Information (any of "HW mode", "SW mode", and "NW mode") indicating an operation mode to be described later set to the page, is set in the operation mode **513**. Note that the operation mode may be set page by page, however, the way in which setting is performed is not limited to the above and the mode may be managed in units different from page units. For example, the operation mode may be managed in units of virtual LDEVs.

Information ("Y" or "N") indicating whether the operation mode of that page is permitted to be automatically changed is set in the operation mode change permission **514**. As for the page in which the operation mode is not permitted to be changed (the page in which "N" is set), a change of operation modes to be described later is prohibited.

The IO load management table **124** manages IO load information, for each page of the virtual LDEV, acquired by the IO load information acquisition PG **116**. FIG. **9** shows an example of the IO load management table **124** which is stored in the first storage apparatus **10**, while FIG. **10** shows an example of the IO load management table **124** which is stored in the second storage apparatus **10**.

Note that in the following description, the IO loads are measured page by page of the virtual LDEV, however, the units in which the IO loads are measured may be changed according to management units of the operation mode. Further, the operation mode change upper limit threshold, the operation mode change lower limit threshold as well as the operation mode change upper limit threshold (Read) may also be managed in virtual LDEV units. For example, the IO loads may be measured for each virtual LDEVs and managed in the IO load management table when the mode is managed in virtual LDEV units.

As shown in these figures, the IO load management table **124** is configured with records including items of LDEV **611**, a page **612**, an access count (total) **613**, an access count (Read) **614**, an access count (Write) **615**, an operation mode change upper limit threshold **616**, an operation mode change lower limit threshold **617**, and an operation mode change upper limit threshold (Read) **618**. Hereinafter, explanation on each item will be given with the IO load management table **124** stored in the first storage apparatus **10** of FIG. **9** and the second storage apparatus **10** of FIG. **10**, as an example.

First of all, an identifier of virtual LDEV (virtual LDEV-ID) is set in the virtual LDEV **611**.

Page ID of that virtual LDEV is set in the page **612**. Note that an address specifying the storage area of the virtual LDEV corresponding to the page is set in the brackets attached to the page ID.

In the access count (total) **613**, there is set the access count (for example, the sum of the numbers of received write requests and received read requests) acquired per unit time that had occurred to each page for the first storage apparatus **10** (the second storage apparatus **10** in the case of FIG. **10**).

In the access count (Read) **614**, there is set the access count (for example, the number of read request received) acquired per unit time that had occurred to each page for the first storage apparatus **10** (the second storage apparatus **10** in the case of FIG. **10**).

In the access count (Write) **615**, there is set the access count (for example, the number of write request received) acquired per unit time that had occurred to each page for the first storage apparatus **10** (the second storage apparatus **10** in the case of FIG. **10**).

In the operation mode change upper limit threshold **616**, there is set an upper limit threshold (a first upper limit threshold, a second upper limit threshold) of the access count (the (total) value of the access count **613**).

In the operation mode change lower limit threshold **617**, there is set a lower limit threshold of the access count (the (total) value of the access count **613**).

In the operation mode change upper limit threshold (Read) **618**, there is set an upper limit threshold (a third upper limit threshold, a fourth upper limit threshold) of the access count (a value of the access count (Read) **614**).

=Basic Operations of the Storage Apparatus=

When the communication control unit **11** of the storage apparatus **10** receives an IO request from the host computer **2**, the storage apparatus **10** basically operates as follows.

For example, when the storage apparatus **10** receives a write request as an IO request from the host computer **2**, the communication control unit **11** firstly notifies the data transfer device **12** of the event.

When receiving the notification, the data transfer device **12** generates a drive write instruction corresponding to the write request, then transmits the write instruction to the drive control unit **13**, and stores write data for the write request into the cache memory **14**.

The communication control unit **11** transmits a response (a write completion report) for the write request to the host computer **2** after confirming that the data transfer device **12** had stored the write data in the cache memory **14**.

When receiving the drive write instruction from the data transfer device **12**, the drive control unit **13** registers this in a write processing queue. The drive control unit **13** sequentially reads the drive write instruction registered in the write processing queue, and reads write data designated thereto from the cache memory **14**, and then writes the read data in the storage drive **17**.

In addition, for example, when the storage apparatus **10** receives a read request as an IO request from the host computer **2**, the communication control unit **11** firstly notifies the drive control unit **13** of the event.

When receiving the notification, the drive control unit **13** reads the data which is designated by aforementioned data read request (for example, the one designated by LDEV-ID (virtual LDEV-ID) and LBA (Logical Block Address)). Note that the reading of the data from the storage drive **17** is omitted if the already-read data exists in the cache memory **14**.

The data read by the drive control unit **13** is read by the data transfer device **12** from the cache memory **14**, and the communication control unit **11** transmits the read data as a response to the read request to the host computer **2**.

=Virtual LDEV=

As described above, the first storage apparatus **10** and the second storage apparatus **10** both can provide the host computer **2** with virtual LDEVs to which a same virtual LDEV-ID is assigned. Also, when respectively receiving IO requests for virtual LDEV-IDs from the host computer **2**, the first storage apparatus **10** and the second storage apparatus **10** behave toward the host computer **2** as if the LDEVs (the first LDEV and the second LDEV associated with the virtual LDEV-ID) separately included in each of the first storage apparatus **10** and second storage apparatus **10** were LDEVs of the alternate path configuration set to a single storage apparatus.

This type of mechanism is implemented using the virtual production number **411** and the virtual LDEV **412** which are managed by the above-described virtual LDEV management table **122**. Hereinafter, the operations of the first storage apparatus **10** and the second storage apparatus **10** regarding this mechanism are described.

The storage apparatus **10** (the first storage apparatus **10** or the second storage apparatus **10**) transmits a login command to the host computer **2** when the host computer **2** and the storage apparatus **10** are coupled via a communication cable (the first communication network **5**). Note that the host computer **2** may be made to transmit a login command to the storage apparatus **10** (the first storage apparatus **10** or the second storage apparatus **10**).

Thereafter, at least the following two processings are executed in the login sequence. First, the host computer **2** issues an apparatus information acquisition request to the storage apparatus **10**. The storage apparatus **10** that has received the apparatus information acquisition request sends to the host computer **2** a virtual product number assigned to the storage apparatus **10** itself and a port ID (for example, WWN assigned to an HBA port) of the communication control unit **11** of the storage apparatus **10** itself. Next, when receiving the virtual product number and the port ID from the storage apparatus **10**, the host computer **2** requests (for example, requests by an Inquiry command in accordance with the SCSI standards) for information of the virtual LDEV (virtual LDEV-ID) from the storage apparatus **10** to be the transmission destination of the IO request.

Note that the host computer **2** specifies the storage apparatus **10** to be a transmission destination of the IO request with the received virtual product number. Also, the host computer **2** generates the request without distinguishing the virtual product number from the product number which is uniquely assigned to each storage apparatus **10** (hereinafter also referred to as a real product number).

When receiving the request, the storage apparatus **10** (the storage apparatus **10** specified by the virtual product number) returns to the host computer **2** information including the virtual product number, the port ID and information of the virtual LDEV (virtual LDEV-ID). Then the host computer **2** receiving a response from the storage apparatus **10** recognizes the storage apparatus **10** as a single virtual storage apparatus instead of a plurality of physical storage apparatuses (the first storage apparatus **10** and the second storage apparatus **10**). Note that to prevent the host computer **2** from making a wrong recognition, the same virtual product number is used for the product number included in the response to the apparatus information acquisition request and the product number included in the response to the Inquiry request.

In the IO request thereafter, the host computer **2** generates an IO request in which the port ID and information of the virtual LDEV (virtual LDEV-ID) included in the information are designated as an address to transmit to the storage apparatus **10**.

When receiving the IO request, the storage apparatus **10** performs processing in response to the IO request for the storage area designated by the IO request (the storage area specified by the port ID and the virtual LDEV).

In this manner, the storage apparatus **10** presents, to the host computer **2**, a virtual product number commonly assigned to each of the plurality of storage apparatuses **10** and virtual LDEV commonly assigned to different LDEVs in the plurality of storage apparatuses **10**. In this way, the host computer **2** is provided with the storage areas of the LDEVs individually included in the storage apparatuses **10** (the first LDEV and second LDEV associated with the virtual LDEV-ID) as if a single virtual LDEV assigned the virtual LDEV-ID were present.

=Data Management Method=

The storage apparatus **10** (the first storage apparatus **10**, the second storage apparatus **10**) can manage the data received from the host computer **2** by three data management methods to be described below. Note that in the present embodiment, the above-described page is set as a unit in the data management method. Hereinafter, each data management method is sequentially described.

<Dual Management Method>

The dual management method is a method to redundantly manage data received by the first storage apparatus **10** and the second storage apparatus **10** from the host computer **2**. When the dual management method is performed, both the first storage apparatus **10** and the second storage apparatus **10** are set in an "HA mode" among the operation modes to be described later. Note that the "HA mode" may be set for each page of the virtual LDEVs or may be set for each virtual LDEV.

FIG. **11** schematically shows an operation of a storage system when the dual management method is carried out. FIG. **11** shows an operation of the storage system when the first storage apparatus **10** receives a write request as an IO request from the host computer **2**. Note that the following description gives an example of a case where the second storage apparatus **10** side has the later-described "Master" attribute assigned to the virtual LDEV.

As shown in FIG. **11**, when receiving a write request and write data from the host computer **2** (**S1111**), the first storage apparatus **10** transfers the write request and the write data to the second storage apparatus **10** (**S1112**).

When receiving the write request and write data from the first storage apparatus **10**, the second storage apparatus **10** writes the received write data in the LDEV (second LDEV) corresponding to the virtual LDEV which is designated by the write request (**S1113**). Note that the write request and the write data may be simply stored in the cache memory **14**.

When the writing is completed, the second storage apparatus **10** transmits a response (a completion report) to the first storage apparatus **10** (**S1114**). Note that the response may be transmitted at the point at which the write request and the write data are stored in the cache memory **14**.

When receiving the response from the second storage apparatus **10**, the first storage apparatus **10** then writes the write data in the LDEV (first LDEV) corresponding to the virtual LDEV which is designated by the write request (**S1115**).

When the writing is completed, the first storage apparatus **10** transmits a response (a completion report) for the write

request received at S1111 to the host computer 2 which is the transmission source of the write request (S1116).

Note that when the first storage apparatus 10 is assigned the later described "Master" attribute to the virtual LDEV is as follows.

First, the first storage apparatus 10 transmits a completion report, a write request and write data to the second storage apparatus 10 after the first storage apparatus 10 writes in the first LDEV associated with the virtual LDEV. Then the second storage apparatus 10 transmits a completion report to the first storage apparatus 10 after the second storage apparatus 10 writes in the second LDEV associated with the virtual LDEV, and thereafter the first storage apparatus 10 transmits a completion report on the write request to the host computer 2.

Further, when the second storage apparatus 10 receives the write request from the host computer 2, the positions of the first storage apparatus 10 and the second storage apparatus 10 are reversed, and a processing similar to that above is performed.

In addition, although the above description is given for the case where a write request is received as an IO request from the host computer 2, when the first storage apparatus 10 or the second storage apparatus 10 receives a read request from the host computer 2, the storage apparatus 10 (the first storage apparatus 10 or the second storage apparatus 10) receiving the read request carries out the above-described basic operation and returns a response to the host computer 2.

In this manner, in the dual management method, the data received from the host computer 2 is redundantly managed in both the first storage apparatus 10 and the second storage apparatus 10. Thus, availability of the data received from the host computer 2 can be increased. Further, a response can be made with data in the first LDEV of the first storage apparatus 10 to the read request received by the first storage apparatus 10, and a response can be made with data in the second LDEV of the second storage apparatus 10 to the read request received by the second storage apparatus 10 thus the performance of the entire information processing system 1 can be improved for the read request.

Note that in the dual management method, the storage apparatus 10 receiving the write request needs to wait for the completion of writing in the other storage apparatus 10. Thus, a response performance (response speed) to the host computer 2 is deteriorated.

<IO Request Transfer Method>

The IO request transfer method is a method in which only one of the first storage apparatus 10 and the second storage apparatus 10 manages the data received from the host computer 2. When the IO request transfer method is carried out, an "SW mode" among the operation modes to be described later is set to the storage apparatus 10 which does not manage the data, while an "NM mode" among the operation modes to be described later is set to the storage apparatus 10 which manages the data. The IO request transfer method is a processing method when the storage apparatus 10 set to "SW mode" receives the IO request. Note that, the operation modes in "SW mode" or the "NM mode" may be set for each page of the virtual LDEVs or may be set for each virtual LDEV s.

FIG. 12 schematically shows an operation of a storage system when the IO request transfer method is performed. In this example, an "SW mode" is set in the page of the virtual LDEV (or virtual LDEV) on the first storage apparatus 10 side and an "NM mode" is set in the page of the virtual LDEV (or virtual LDEV) on the second storage apparatus 10 side.

As shown in FIG. 12, when receiving an IO request (a write request or a read request) from the host computer 2 (S1211), the first storage apparatus 10 transfers the received IO request to the second storage apparatus 10 (S1212). Note that during processing S1211 and S1212, only resources of the communication control unit 11 are used among the resources which are included in the first storage apparatus 10, and resources of the cache memory 14, the drive control unit 13, and the storage drive 17 of the first storage apparatus 10 are not used. For this reason, a load on the first storage apparatus 10 is suppressed at minimum during processing S1211 and S1212.

When receiving the IO request transferred from the first storage apparatus 10, the second storage apparatus 10 carries out the basic operation for the IO request to the LDEV associated with the virtual LDEV (S1213), and transmits a response (a completion report. When the IO request is a read request, data which is further read from the storage drive 17) for the IO request to the first storage apparatus 10 (S1214).

When receiving the response from the second storage apparatus 10, the first storage apparatus 10 transmits a response (a completion report. When the IO request is a read request, data further read from the storage drive 17) for the IO request received at S1211 to the host computer 2 which is a transmission source of the IO request (S1215).

As described above, in the IO request transfer method, one of the storage apparatuses 10 has the other of the storage apparatuses 10 carry out substantive processing of the IO request received from the host computer 2. For this reason, for example, when the resources of the one of the storage apparatuses 10 (for example, resources of at least any one of the cache memory 14, the drive control unit 13, and the storage drive 17) is lacking, the deterioration of services to the host computer 2 can be effectively prevented. Also, since the operation mode of the page of the virtual LDEV (or virtual LDEV) on the second storage apparatus 10 side is set to the "NM mode", the response performance is improved as compared with that of the dual management method as for the write request which is directly received by the second storage apparatus 10 from the host computer 2.

For processing an IO request, the IO request transfer method involves transferring the IO request from one of the storage apparatuses 10 to the other of the storage apparatuses 10 and transmitting a response (such as a completion report) from the other of the storage apparatuses 10 to the one of the storage apparatuses 10. Accordingly, the first storage apparatus 10 would make a reply to the host computer 2 with a lowered response performance (response speed). For this reason, the IO request transfer method is suitable in a case, for example, where the first storage apparatus 10 side has small numbers of IOs or where resources of the first storage apparatus 10 are preferentially reserved.

<Normal Method>

In the normal method, similar to the IO request transfer method, the page of the virtual LDEV (or virtual LDEV) on the storage apparatus 10 side that does not manage data is set to "SW mode", and the page of the virtual LDEV (or virtual LDEV) on the storage apparatus 10 side that manages data is set to "NM mode". The normal method is a processing method carried out when the storage apparatus 10 set to the "NM mode" receives an IO request.

FIG. 13 schematically shows an operation when a normal method is carried out. In other words, the processing is for the case when the second storage apparatus side receives an IO request to the virtual LDEV in the configuration shown in FIG. 12.

As shown in FIG. 13, when receiving an IO request (a write request or a read request) to the virtual LDEV from the host computer 2 (S1311), the first storage apparatus 10 carries out a basic operation for the IO request to the second LDEV

associated with the virtual LDEV (S1312) and then returns a response to the IO request to the host computer 2 (S1313).

=Attribute of LDEV=

By the way, in a case where the first storage apparatus 10 and the second storage apparatus 10 simultaneously receive write requests for the same virtual LDEV from the host computer 2 when the data received from the host computer 2 is managed by the above-described dual management method, both of the storage apparatuses 10 transmit their respective write requests to the other storage apparatuses 10. As a result, there is a possibility of causing deadlock. The above-described attribute of LDEV (a first attribute, a second attribute) is used to prevent the occurrence of the deadlock.

In other words, a "Master" attribute is assigned to any one of LDEVs of the storage apparatuses 10, which are associated with the same virtual LDEV, and a "Slave" attribute is assigned to the other.

When the first storage apparatus 10 and the second storage apparatus 10 simultaneously receive write requests for the same virtual LDEV from the host computer 2, the storage apparatus 10 assigned the "Master" attribute acquires a lock for the LDEV of itself without checking the lock (or reserve) state of the other storage apparatus 10 and performs writing on the LDEV.

On the other hand, the storage apparatus 10 assigned the "Slave" attribute always transfers the write request and write data received from the host computer 2 to the storage apparatus 10 assigned the "Master" attribute so that a write processing for the aforementioned write request is carried out in the storage apparatus 10 to which the "Master" attribute is assigned in advance, and performs writing on LDEV of itself after confirming that the lock in the storage apparatus 10 assigned the "Master" attribute is released.

In this manner, when the first storage apparatus 10 and the second storage apparatus 10 simultaneously receive write requests for the same LDEV from the host computer 2, the "Slave" side performs writing on LDEV after checking the presence of a lock on the "Master" side. Accordingly, the occurrence of a deadlock can be certainly prevented. And thereby, the order in which writing is carried out can be controlled so that consistency of data can be guaranteed.

Note that in the present embodiment, write processing is first carried out in the storage apparatus 10 managing the LDEV to which "Master" attribute is assigned when receiving a write request to the virtual LDEV according to the dual management method and thereafter, write processing is carried out in the storage apparatus 10 managing the LDEV to which "Slave attribute" is assigned to prevent a deadlock from occurring.

=IO Processing According to Operation Modes=

The storage apparatus 10 performs IO processing according to the operation modes (a "HA mode", "SW mode", and "NW mode") which are set in a page of the virtual LDEV to be a target of the IO request. Hereinafter, the IO processing of the storage apparatus 10 in each operation mode is described.

<HA Mode Write Processing>

FIG. 14 is a flowchart illustrating processing which is performed by each of the first storage apparatus 10 and the second storage apparatus 10 when the first storage apparatus 10 receives a write request for a page set to "HA mode" ("HA mode" may be set to the virtual LDEV) from the host computer 2, and attribute "Slave" is assigned to the first LDEV in the first storage apparatus associated with the virtual LDEV (hereinafter referred to as HA mode write processing S1400).

When receiving a write request for a page set to "HA mode" in the virtual LDEV (S1411: YES), the first storage apparatus 10 receives write data for that write request (S1412), and then transmits the received write request and write data to the second storage apparatus 10 (S1413).

When receiving the write request and the write data from the first storage apparatus 10 (S1414: YES), the second storage apparatus 10 stores the received write data in the cache memory 14 (S1415), and then transmits to the first storage apparatus 10 a response indicating that writing has been completed (S1416). Note that thereafter, the second storage apparatus 10 writes write data from the cache memory 14 to the second LDEV associated with the virtual LDEV.

When receiving the response from the second storage apparatus 10 (S1417: YES), the first storage apparatus 10 receives write data from the host computer 2 (S1418). Note that it is also possible that the write data received at S1412 is stored by the first storage apparatus 10 without making a request for the write data again to the host computer 2 as described above.

Subsequently, the first storage apparatus 10 stores the write data in the cache memory 14 (S1419), and, thereafter, transmits a response (a completion report) for the write request to the host computer 2 (S1420). Note that thereafter, the first storage apparatus 10 destages write data from the cache memory 14 to the first LDEV associated with the virtual LDEV.

Note that the following processing is carried out when the first LDEV associated with the virtual LDEV on the first storage 10 side is assigned the "Master" attribute.

That is, after the first storage apparatus 10 writes a write request and write data in the cache memory 14, the first storage apparatus 10 transmits a write request and write data to the second storage apparatus 10. And the second storage apparatus 10 transmits a completion report to the first storage apparatus 10 after writing data in the cache memory 14. Thereafter, the first storage apparatus 10 transmits a completion report for the write request to the host computer 2. Here, the first storage apparatus 10 destages write data from the cache memory 14 to the first LDEV associated with the virtual LDEV. The second storage apparatus 10 destages write data from the cache memory 14 to the second LDEV associated with the virtual LDEV.

<HA Mode Read Processing>

FIG. 15 is a flowchart illustrating processing which is performed by the storage apparatus 10 (the first storage apparatus 10 or the second storage apparatus 10) when the storage apparatus 10 receives a read request for a page set to "HA mode" in the virtual LDEV ("HA mode" may be set to a virtual LDEV) from the host computer 2 (hereinafter referred to as HA mode read processing S1500). Hereinafter, the HA mode read processing S1500 is described with reference to FIG. 15.

When receiving a read request for a page set to "HA mode" ("HA mode" may be set to a virtual LDEV) (S1511: YES), the storage apparatus 10 determines whether data which is a read target of the read request (hereinafter referred to as target data) is present in the cache memory 14 (staging is performed or not) (S1512).

When the target data is present in the cache memory 14 (S1512: YES), the storage apparatus 10 transmits a response to the read request to the host computer 2 together with the data (S1514).

On the other hand, when the target data is not present in the cache memory 14 (S1512: NO), the storage apparatus 10 loads the target data from the storage drive 17 providing storage area for the first LDEV or the second LDEV associated with the virtual LDEV to the cache memory 14 (S1513),

and, thereafter, transmits a response to the read request to the host computer **2** together with the loaded data (S**1514**).

<SW Mode Write Processing>

FIG. **16** is a flowchart illustrating processing (hereinafter referred to as SW mode write processing S**1600**) which is performed by each of the first storage apparatus **10** and the second storage apparatus **10** when the first storage apparatus **10** receives from the host computer **2** a write request for a page in the virtual LDEV set to "SW mode" ("SW mode" may be set to the virtual LDEV). Hereinafter, the SW mode write processing S**1600** is described with reference to FIG. **16**.

When receiving a write request for a page set to "SW mode" ("SW mode" may be set to the virtual LDEV) (S**1611**: YES), the first storage apparatus **10** receives write data for the write request from the host computer **2** (S**1612**), and then transmits the received write request and write data to the second storage apparatus **10** (S**1613**). Note that when the processing of S**1611** to S**1613** is carried out, only resources of the communication control unit **11** are used and resources of the cache memory **14**, the drive control unit **13**, and the storage drive **17** are not used.

When receiving the write request and write data from the first storage apparatus **10**

(S**1614**: YES), the second storage apparatus **10** stores the received write data in the cache memory **14** (S**1615**), and then transmits a response indicating that writing of the data is completed to the first storage apparatus **10** (S**1616**). Note that thereafter, the second storage apparatus **10** writes write data from the cache memory **14** to the second LDEV associated with the virtual LDEV.

When receiving the response from the second storage apparatus **10** (S**1617**: YES), the first storage apparatus **10** transmits a response (a completion report) for the write request to the host computer **2** (S**1618**).

<SW Mode Read Processing>

FIG. **17** is a flowchart illustrating processing (hereinafter referred to as SW mode read processing S**1700**) which is performed by each of the first storage apparatus **10** and the second storage apparatus **10** when the first storage apparatus **10** receives from the host computer **2** a read request for a page in the virtual LDEV set to "SW mode" ("SW mode" may be set to the virtual LDEV). Hereinafter, the SW mode read processing S**1700** is described with reference to FIG. **17**.

When receiving a read request for a page in the virtual LDEV set to "SW mode" ("SW mode" may be set to the virtual LDEV) (S**1711**: YES), the first storage apparatus **10** transmits the received read request to the second storage apparatus **10** (S**1712**).

When receiving the read request from the first storage apparatus **10** (S**1713**: YES), the second storage apparatus **10** determines whether the data which is a read target of the read request (hereinafter referred to as target data) is present in the cache memory **14** (S**1714**).

When the target data is present in the cache memory **14** (S**1714**: YES), the second storage apparatus **10** transmits a response to the read request to the first storage apparatus **10** together with the data (S**1716**).

On the other hand, when the target data does not exist in the cache memory **14** (S**1714**: NO), the second storage apparatus **10** loads the target data from the storage drive **17** configuring the second LDEV for the virtual LDEV to the cache memory **14** (S**1715**), and, thereafter, transmits a response to the first storage apparatus **10** together with the loaded data (S**1716**).

When receiving the response from the second storage apparatus **10** (S**1717**: YES), the first storage apparatus **10** transmits a response (a completion report) for the read request to the host computer **2** together with the loaded data which is received from the second storage apparatus **10** together with the response (S**1718**).

<NM Mode Write Processing>

FIG. **18** is a flowchart illustrating processing which is carried out by the storage apparatus **10** (the first storage apparatus **10** or the second storage apparatus **10**) receiving a write request when the storage apparatus **10** receives the write request for a page in the virtual LDEV set to "NM mode" ("NM mode" may be set to the virtual LDEV) from the host computer **2** (hereinafter referred to as NM mode write processing S**1800**). Hereinafter, the NM mode write processing S**1800** is described with reference to FIG. **18**.

When receiving a write request for a page in the virtual LDEV set to "NM" mode" ("NM mode" may be set to the virtual LDEV) (S**1811**: YES), the storage apparatus **10** receives write data for the write request from the host computer **2** (S**1812**).

Subsequently, the storage apparatus **10** stores the write data in the cache memory **14** for implementation (S**1813**) and, thereafter, transmits a response (a completion response) for the write request to the host computer **2** (S**1814**). Further thereafter, the storage apparatus **10** stores the write data from the cache memory **14** in the LDEV associated with the virtual LDEV.

<NM Mode Read Processing>

FIG. **19** is a flowchart illustrating processing which is performed by the storage apparatus **10** (the first storage apparatus **10** or the second storage apparatus **10**) receiving a read request when the storage apparatus **10** receives the read request for a page in the virtual LDEV set to "NM mode" ("NM mode" may be set to the virtual LDEV) from the host computer **2** (hereinafter referred to as NM mode read processing S**1900**). Hereinafter, the NM mode read processing S**1900** is described with reference to FIG. **19**.

When receiving a read request for a page set to "NM mode" ("NM mode" may be set to the virtual LDEV) (S**1911**: YES), the storage apparatus **10** determines whether data which is a read target of the read request (hereinafter referred to as target data) is present in the cache memory **14** (whether staging is performed)(S**1912**).

When the target data is present in the cache memory **14** (S**1912**: YES), the storage apparatus **10** transmits a response to the read request to the host computer **2** together with the data (S**1914**).

On the other hand, when the target data is not present in the cache memory **14** (S**1912**: NO), the storage apparatus **10** loads the target data from the storage drive **17** providing the LDEV associated with the virtual LDEV to the cache memory **14** (S**1913**), and then transmits a response to the read request to the host computer **2** together with the loaded data (S**1914**).

=Change of Data Management Method According to IO Load=

The management apparatus **3** determines an operation mode to be set for each page based on the contents (IO load of each page) of the IO load management table **124** of each of the first storage apparatus **10** and the second storage apparatus **10** and sets the operation mode of each page so that the operation mode of each page would be the determined operation mode (sets the contents of the operation mode management table **123** of each of the first storage apparatus **10** and the second storage apparatus **10**). With this operation, the data received from the host computer **2** is managed according an appropriate data management method. Thus, the resources of the storage apparatus **10** can be effectively used and a response performance to the host computer **2** can be secured.

FIG. **20** is a flowchart illustrating processing (hereinafter referred to as operation mode setting processing S**2000**) of setting contents of the operation mode management table **123** of the first storage apparatus **10** and the second storage apparatus **10** so that the management apparatus **3** determines an operation mode of each page and an operation mode of each page would be the determined operation mode. Hereinafter, description is given with reference to FIG. **20**.

When timing to start processing relating to operation mode setting arrives (S**2011**: YES), the management apparatus **3** firstly acquires tables (the virtual LDEV management table **122**, the operation mode management table **123**, the IO load management table **124**) to be used for the aforementioned processing from each storage apparatus **10** (the first storage apparatus **10** and the second storage apparatus **10**) (S**2012**). Note that not all the information included in the table but a part of the information necessary for the following processings may be acquired.

Note that the management apparatus **3** determines the arrival of a timing to start processing relating to operation mode setting when, for example, an administrator or the like clearly makes an instruction to the management apparatus **3** or when the time scheduled in advance (designated as needed, on a regular basis or the like) arrives. Also, the tables need not be acquired upon arrival of the timing, but may be acquired as needed from the storage apparatus **10**.

Next, the management apparatus **3** selects a page of a virtual LDEV (hereinafter referred to as a first page) from the operation mode management table **123** (hereinafter referred to as the first operation mode management table **123**) acquired from the first storage apparatus **10** (S**2013**).

Subsequently, based on the virtual LDEV management table **122** and the operation mode management table acquired from the second storage apparatus **10** (hereinafter referred to as the second operation mode management table **123**), the management apparatus **3** specifies a page equivalent to the first page selected at S**2013** (in other words, a page of LDEV having the virtual LDEV-ID including the first page in the first storage apparatus **10**, the page equivalent to the first page (a page in which the same data redundantly managed is stored) in the virtual LDEV in the second storage apparatus, and hereinafter referred to as a second page)(S**2014**).

Thereafter, the management apparatus **3** acquires an IO load (at least one value among access count (total) **613**, access count (Read) **614**, and access count (Write) **615**, and hereinafter referred to as the first IO load) of the first page selected at S**2013** from the IO load management table **124** (hereinafter referred to as the first IO load management table **124**) acquired from the first storage apparatus **10** (S**2015**).

Also, the management apparatus **3** acquires an IO load (at least one value among access count (total) **613**, access count (Read) **614**, and access count (Write) **615**, and hereinafter referred to as the second IO load) of the second page specified at S**2014** from the IO load management table **124** (hereinafter referred to as the second IO load management table **124**) acquired from the second storage apparatus **10** (S**2016**).

Next, the management apparatus **3** determines an operation mode to be set for each of the first page and the second page based on the first IO load acquired at S**2015** and the second IO load acquired at. S**2016**.

For example, when a ratio of the second IO load to the first IO load exceeds a predetermined threshold (the second IO load>>the first IO load), the managementapparatus **3** selects the IO request transfer method in view of improving the response performance to the host computer **2** as a whole storage system by concentrating the load on the second storage apparatus **10** side, and determines the operation mode to be set to the first page as the "SW mode" and the operation mode to be set to the second page as the "NM mode".

Specifically, for example, the management apparatus **3** determines the operation mode to be set in the first page as the "SW mode" and the operation mode to be set in the second page as the "NM mode" when the second IO load (the access count (total) **613** value in the second IO load management table **124**) exceeds an upper limit threshold (the operation mode change upper limit threshold **616** value of the second IO load management table **124**) and the first IO load (the access count (total) **613** value in the first IO load management table **124**) is smaller than a lower limit threshold (the operation mode change lower limit threshold **617** value in the first IO load management table **124**).

Also, for example, when the ratio of the first IO load to the second IO load exceeds a predetermined threshold (the first IO load>>the second IO load), the management apparatus **3** selects the IO request transfer method in view of improving response performance to the host computer **2** as a whole storage system by concentrating loads on the first storage apparatus **10** side, and determines the operation mode to be set in the first page to "NM mode" and the operation mode to be set in the second page to "SW mode".

Specifically, for example, the management apparatus **3** determines the operation mode to be set in the first page to "NM mode" and the operation mode to be set in the second page to "SW mode" when the second IO load is smaller than the lower limit threshold (the operation mode change lower limit threshold **617** value in the second IO load management table **124**) and the first IO load exceeds the upper limit threshold (the operation mode change upper limit threshold **616** value in the first IO load management table **124**).

Also, for example, when both the first IO load and the second IO load are large, the management apparatus **3** selects the dual management method in view of improving availability of the data received from the host computer **2** and determines the operation mode to be set in the first page and the second page to "HA mode".

Specifically, for example, the management apparatus **3** determines the operation mode to be set in the first page and the second page to "HA mode" when the first IO load (the access count (total) **613** value in the first IO load management table **124**) exceeds the first upper limit threshold (the operation mode change upper limit threshold **616** value in the first IO load management table **124**) and the second IO load (the access count (total) **613** value in the second IO load management table **124**) exceeds the second upper limit threshold (the operation mode change upper limit threshold **616** value in the second IO load management table **124**).

Further, both the first IO load and the second IO load may determine whether or not the load due to a read request is heavy. This is because the IO load on the storage apparatus **10** by a read request is lighter compared to a write request, so the effect on the response performance to the host computer **2** is small even when the dual management method is selected.

Specifically, the management apparatus **3** determines the operation mode to be set in the first page and the second page as the "HA mode" when the first IO load (the access count (total) **613** value in the first IO load management table **124**) exceeds the first upper limit threshold (the operation mode change upper limit threshold **616** value of the first IO load management table **124**), and the second IO load (the access count (total) **613** value in the second IO load management table **124**) exceeds the second upper limit threshold (the operation mode change upper limit threshold **616** value of the second IO load management table **124**), and the first IO load for the read request (the access count (Read) **614** value in the

first IO load management table **124**) exceeds the third upper limit threshold (the operation mode change upper limit threshold (Read) **618** value of the first IO load management table **124**), and the second IO load for the read request (the access count (Read) **614** value in the second IO load management table **124**) exceeds the fourth upper limit threshold (the operation mode change upper limit threshold (Read) **618** value of the second IO load management table **124**).

When both the first IO load and the second IO load are not in any of the aforementioned states, the current mode is maintained without being changed.

Subsequently, the management apparatus **3** refers to the first operation mode management table **123** and the second operation mode management table **123**, and determines whether the operation mode of each of the first page and the second page determined at S**2017** is the same as the currently-set operation mode (S**2018**). When the determined operation mode is the same as the currently-set operation mode (S**2018**: YES), the step returns to the processing of S**2011**.

On the other hand, when the determined operation mode is different from the currently-set operation mode (S**2018**: NO), the management apparatus **3** transmits an instruction to change the operation mode (hereinafter referred to as an operation mode change instruction) to the storage apparatus **10** which needs the operation mode to be changed (S**2019**). Thereafter, the processing returns to S**2011**. Note that processing which is performed by the storage apparatus **10** when the operation mode change instruction is received from the management apparatus **3** is described later.

FIG. **21** is a flowchart illustrating processing of changing the operation mode when the first storage apparatus **10** and the second storage apparatus **10** manages the operation mode of the virtual LDEVs in units of virtual LDEVs.

The management apparatus **3** determines an operation mode to be set for each virtual LDEV based on the contents (IO load of each virtual LDEV) of the IO load management table **124** of each of the first storage apparatus **10** and the second storage apparatus **10** and sets the operation mode of each virtual LDEV so that the operation mode of each virtual LDEV becomes the determined operation mode (sets the contents of the operation mode management table **123** of each of the first storage apparatus **10** and the second storage apparatus **10**). With this operation, the data received from the host computer **2** is managed according to an appropriate data management method. Thus, the resources of the storage apparatus **10** can be effectively used and response performance to the host computer **2** can be secured

In the following description the differences between FIG. **20** will be given.

The management apparatus **3** selects a virtual LDEV from the operation mode management table **123** (hereinafter referred to as the first operation mode management table **123**) acquired from the first storage apparatus **10** (S**2113**).

Subsequently, the management apparatus **3** determines the virtual LDEV having the same virtual LDEV-ID as that of the virtual LDEV selected at S**2113** based on the operation load management table **123** (hereinafter referred to as the second IO load management table **123**) acquired from the second storage apparatus **10** (S**2114**).

Next, the management apparatus **3** acquires an IO load (at least one value among access count (total) **613**, access count (Read) **614**, and access count (Write) **615**, and hereinafter referred to as the first IO load) of the virtual LDEV selected at S**2113** from the IO load management table **124** (hereinafter referred to as the first IO load management table **124**) acquired from the first storage apparatus **10** (S**2115**).

Further, the third management apparatus **3** acquires an IO load (at least one value among access count (total) **613**, access count (Read) **614**, and access count (Write) **615**, and hereinafter referred to as the second IO load) of the virtual LDEV specified at S**2114** from the IO load management table **124** (hereinafter referred to as the second IO load management table **124**) acquired from the second storage apparatus **10** (S**2016**).

Next, the management apparatus **3** determines an operation mode to be set for the virtual LDEVs in each of the first storage apparatus **10** and the second storage apparatus **10** based on the first IO load acquired at S**2115** and the second IO load acquired at S**2116** (S**2117**).

For example, when a ratio of the second IO load to the first IO load exceeds a predetermined threshold (the second IO load>>the first IO load), the management apparatus **3** selects the IO request transfer method in view of improving the response performance to the host computer **2** as a whole storage system by concentrating the load on the second storage apparatus **10** side, and determines the operation mode to be set to the virtual LDEV of the first storage apparatus **10** as the "SW mode" and the operation mode to be set to the virtual LDEV of the second storage apparatus **10** as the "NM mode".

Specifically, for example, the management apparatus **3** determines the operation mode to be set to the virtual LDEV of the first storage apparatus **10** as the "SW mode" and the operation mode to be set to the virtual LDEV of the second storage apparatus **10** as the "NM mode" when the second IO load (the access count (total) **613** value in the second IO load management table **124**) exceeds an upper limit threshold (the operation mode change upper limit threshold **616** value of the second IO load management table **124**) and the first IO load (the access count (total) **613** value in the first IO load management table **124**) is smaller than a lower limit threshold (the operation mode change lower limit threshold **617** value in the first IO load management table **124**).

Also, for example, when the ratio of the first IO load to the second IO load exceeds a predetermined threshold (the first IO load>>the second IO load), the management apparatus **3** selects the IO request transfer method in view of improving response performance to the host computer **2** as a whole storage system by concentrating loads on the first storage apparatus **10** side, and determines the operation mode to be set to the virtual LDEV of the first storage apparatus **10** to "NM mode" and the operation mode to be set to the virtual LDEV of the second storage apparatus **10** to "SW mode".

Specifically, for example, the management apparatus **3** determines the operation mode to be set in the virtual LDEV of the first storage apparatus **10** to "NM mode" and the operation mode to be set in the virtual LDEV of the second storage apparatus **10** to "SW mode" when the second IO load is smaller than the lower limit threshold (the operation mode change lower limit threshold **617** value in the second IO load management table **124**) and the first IO load exceeds the upper limit threshold (the operation mode change upper limit threshold **616** value in the first IO load management table **124**).

Also, for example, when both the first IO load and the second IO load are heavy the management apparatus **3** selects the dual management method in view of improving availability of the data received from the host computer **2** and determines the operation mode to be set to the virtual LDEVs of the first storage apparatus **10** and the second storage apparatus **10** to "HA mode".

Specifically, for example, the management apparatus **3** determines the operation mode to be set in the virtual LDEV of the first storage apparatus **10** and the second storage appa-

ratus **10** to "HA mode" when the first IO load (the access count (total) **613** value in the first IO load management table **124**) exceeds the first upper limit threshold (the operation mode change upper limit threshold **616** value in the first IO load management table **124**) and the second IO load (the access count (total) **613** value in the second IO load management table **124**) exceeds the second upper limit threshold (the operation mode change upper limit threshold **616** value in the second IO load management table **124**).

Further, both the first IO load and the second IO load may determine whether or not the load due to a read request is heavy. This is because the IO load on the storage apparatus **10** by a read request is lighter compared to a write request, so the effect on the response performance to the host computer **2** is small even when the dual management method is selected.

Specifically, the management apparatus **3** determines the operation mode to be set in the virtual LDEV of the first storage apparatus **10** and the second storage apparatus as the "HA mode" when the first IO load (the access count (total) **613** value in the first IO load management table **124**) exceeds the first upper limit threshold (the operation mode change upper limit threshold **616** value of the first IO load management table **124**), and the second IO load (the access count (total) **613** value in the second IO load management table **124**) exceeds the second upper limit threshold (the operation mode change upper limit threshold **616** value of the second IO load management table **124**), and the first IO load for the read request (the access count (Read) **614** value in the first IO load management table **124**) exceeds the third upper limit threshold (the operation mode change upper limit threshold (Read) **618** value of the first IO load management table **124**), and the second IO load for the read request (the access count (Read) **614** value in the second IO load management table **124**) exceeds the fourth upper limit threshold (the operation mode change upper limit threshold (Read) **618** value of the second IO load management table **124**).

Subsequently, the management apparatus **3** refers to the first operation mode management table **123** and the second operation mode management table **123**, and determines whether the operation mode of each of the virtual LDEV of the first storage apparatus **10** and the second storage apparatus **10** determined at S**2117** is the same as the currently-set operation mode (S**2118**).

By the way, in the above-described operation mode setting processing S**2000** or S**2100**, mainly the management apparatus **3** performs the setting of the operation mode. However, for example, mainly the host computer **2** or the storage apparatus **10** may perform the setting.

Also, when mainly the storage apparatus **10** performs the setting of the operation mode, mainly the storage apparatus **10** having an LDEV to which a "Master" attribute is set may perform the setting of the operation mode. By doing so, the control or setting may be mainly and intensively performed by the storage apparatus **10** having an LDEV to which the "Master" attribute is set. Thus, the maintainability of the storage system can be improved.

As described above, the operation mode is set for each of the first storage apparatus **10** and the second storage apparatus **10** according to the first IO load and the second IO load in the information processing system **2** of the present embodiment, and the management method for the data received from the host computer **2** is properly selected. Thus, the availability of the data received from the host computer **2** can be secured as much as possible and the response performance to the host computer **2** can be also secured, according to the loads of the first storage apparatus **10** and the second storage apparatus **10**.

Also, since the data management method is selected for each page as a unit, a data management method can be carefully selected according to an IO load per page. Thus, with the whole storage system as a whole, the data received from the host computer **2** can be properly managed. However, the mode management and the load management may be performed in units of virtual LDEVs as described above.

=Operation Mode Change Processing=

Described is a processing which is performed when the storage apparatus **10** receives an operation mode change instruction transmitted from the management apparatus **3** in the processing of S**2019**. Note that the processing described below is performed on a page in which an operation mode change is permitted (a page in which "Y" is set in the operation mode change permission **514** of the operation mode management table **123**). Note that, the phrase "first page of the virtual LDEV" is to be read as "virtual LDEV of the first storage apparatus" and the "second page of the virtual LDEV" is to be read as "virtual LDEV of the second storage apparatus" when the operation is set in units of virtual LDEVs.

<When Shifting from the Dual Management Method to the IO Request Transfer Method

FIG. **22** is a flowchart illustrating processing (hereinafter referred to as "method change processing (the dual management method->the IO request transfer method)" S**2200**) which is carried out by each of the first storage apparatus **10** and the second storage apparatus **10** in a case where the operation mode of the first page is set to "SW mode" and the operation mode of the second page is set to "NM mode" (the management of the data received from the host computer **2** is managed by the IO request transfer method) when "HA mode" is set to both the first page of the virtual LDEV of the first storage apparatus **10** and the second page of the virtual LDEV of the second storage apparatus **10** (when data received from the host computer **2** is managed by the dual management method). Hereinafter, the method change processing (the dual management method->the IO request transfer method) S**2200** is described together with reference to FIG. **22**.

When receiving the operation mode change instruction from the management apparatus **3** (S**2211**: YES), the first storage apparatus **10** interrupts the IO processing which is currently executed on the first page in response to the IO request received from the host computer **2** (S**2212**), and transmits an instruction indicating to change the operation mode of the second page to the "NM mode" to the second storage apparatus **10** (S**2213**).

When receiving the aforementioned instruction (S**2214**: YES), the second storage apparatus **10** changes the operation mode of the second page to the "NM mode" (S**2215**), and transmits a notification notifying the first storage apparatus **10** that the change of the operation mode has been completed (S**2216**). Note that after HA mode is changed to NM mode, the second storage apparatus **10** stops transmitting write requests and write data from the second storage apparatus **10** to the first storage apparatus.

When receiving the notification (S**2217**: YES), the first storage apparatus **10** completes the IO processing interrupted at the processing of S**2212** (S**2218**), and transmits write data which has not been transmitted to the first storage apparatus **10** (write data which has not been transferred to the second storage apparatus **10** in the processing of S**1112** in FIG. **11**) to the second storage apparatus **10** (S**2219**).

When receiving the write data (S**2220**), the second storage apparatus **10** reflects this on the second page (S**2221**), and

transmits a notification notifying the first storage apparatus **10** that the reflection has been completed (S**2222**).

When receiving the aforementioned notification (S**2223**: YES), the first storage apparatus **10** changes the operation mode of the first page to the "SW mode" (S**2224**).

Then, the first storage apparatus **10** restarts the IO processing (S**2225**) and releases the storage area of the second page (S**2226**).

According to the above-described method change processing (the dual management method->the IO request transfer method) S**2200**, the IO processing in progress when the dual management method is selected is completed before a shift to the IO request transfer method is made (S**2218** to S**2222**). Thus, the shift to the IO request transfer method can be securely and safely made. Also, the shift from the dual management method to the IO request transfer method can be made without affecting the services to the host computer **2**.

<When Reversing the Relations Between the "SW Mode" and the "NM Mode" of the IO Request Transfer Method>

FIG. **23** is a flowchart illustrating processing (hereinafter referred to as "IO request transfer method reversal processing S**2300**") which is performed by each of the first storage apparatus **10** and the second storage apparatus **10** in a case where the operation mode of the first page is set to "NM mode" and the operation mode of the second page is set to "SW mode" (the relations between the "SW mode" and the "NM mode" of the IO request transfer method are reversed) when the operation mode of the first page of the virtual LDEV of the first storage apparatus **10** is set to "SW mode" and the operation mode of the second page of the virtual LDEV of the second storage apparatus **10** is set to "NM mode" (when the data received from the host computer **2** is managed by the IO request transfer method). Hereinafter, the IO request transfer method reversal processing S**2300** is described together with reference to FIG. **23**.

When receiving an operation mode change instruction from the management apparatus **3** (S**2311**: YES), the first storage apparatus **10** reserves a storage area for the first page (S**2312**).

Subsequently, the first storage apparatus **10** interrupts the IO processing (S**2313**), sets the operation mode of the first page to "NM mode" (S**2314**), and transmits an instruction to change the operation mode of the second page to the "SW mode" to the second storage apparatus **10** (S**2315**).

When receiving the aforementioned instruction (S**2316**: YES), the second storage apparatus **10** changes the operation mode of the second page to the "SW mode" (S**2317**), completes the IO processing relating to the IO request for the second page (S**2318**), and transmits a notification notifying the second storage apparatus **10** that the change of the operation mode has been completed (S**2319**).

When receiving the aforementioned notification (S**2320**: YES), the first storage apparatus **10** starts replicating data of the second page to the first page (S**2321**). When the replication is completed (S**2323**), the first storage apparatus **10** restarts the IO processing (S**2323**) and transmits a notification notifying the second storage apparatus **10** that the data replication has been completed (S**2324**).

When receiving the aforementioned notification (S**2325**: YES), the second storage apparatus **10** releases the storage area of the second page (S**2326**).

According to the above-described **10** request transfer method reversal processing S**2300**, the IO processing in progress before reversal is completed and then the relations between the "SW mode" and the "NM mode" are reversed (S**2318**). Thus, the operation modes can be securely and safely reversed without affecting the services to the host computer **2**.

<When Shifting from the IO Request Transfer Method to the Dual Management Method>

FIG. **24** and FIG. **25** are flowcharts illustrating processing (hereinafter referred to as "method change processing (the IO request transfer method->the dual management method) S**2400**") which is performed by each of the first storage apparatus **10** and the second storage apparatus **10** in a case where the "HA mode" is set for both the first page and the second page (management of data received from the host computer **2** is changed to the dual management method) when the operation mode of the first page of the first storage apparatus **10** is set to "SW mode" and the operation mode of the second page of the second storage apparatus **10** is set to "NM mode" (when data received from the host computer **2** is managed by the IO request transfer method). Hereinafter, method change processing (the IO request transfer method->the dual management method) S**2400** is described with reference to FIGS. **24** and **25**.

When receiving an operation mode change instruction from the management apparatus **3** (S**2411**: YES), the first storage apparatus **10** firstly reserves a storage area for the first page (S**2412**).

Subsequently, the first storage apparatus **10** transmits an instruction to the second storage apparatus **10** to start management (hereinafter referred to as differential management) of information (information relating to update of the second page (such as write request, write data), and hereinafter referred to as differential information) relating to the IO request which is received by the second storage apparatus **10** from the host computer **2** during the replication when the data is later replicated from the second page to the first page (S**2413**).

When receiving the aforementioned instruction (S**2414**: YES), the second storage apparatus **10** starts differential management and transmits a notification notifying the first storage apparatus **10** that the differential management has been started (S**2415**).

When receiving the aforementioned notification (S**2417**: YES), the first storage apparatus **10** starts replication of data from the second page to the first page (S**2418**). Then, when the replication of data has been completed (S**2419**), the second storage apparatus **10** transmits the completion notification to the second storage apparatus **10** (S**2420**).

When receiving the aforementioned notification (S**2421**: YES), the second storage apparatus **10** interrupts the IO processing for the second page (S**2422**), and starts the management at S**2415** and thereafter updates the second page to the latest state based on the differential information acquired so far (S**2423**). Also, the second storage apparatus **10** transmits the differential information to the first storage apparatus **10** (S**2424**).

When receiving the aforementioned differential information (S**2425**: YES) the first storage apparatus **10** updates the first page to the latest state based on the received differential information (S**2426**), and transmits the completion notification to the second storage apparatus **10** (FIG. **25**: S**2427**).

When receiving the aforementioned notification (S**2428**: YES), the second storage apparatus **10** changes the operation mode of the second page to the "HA mode" (S**2429**), and transmits a notification notifying the first storage apparatus **10** that the change of the operation mode is completed (S**2430**).

When receiving the aforementioned instruction (S**2431**: YES), the first storage apparatus **10** sets the operation mode

of the first page to "HA mode" (S2432), and transmits a notification notifying the second storage apparatus **10** that the change of the operation mode is completed (S2433).

When receiving the aforementioned notification (S2434: YES), the second storage apparatus **10** restarts the IO processing (S2435).

According to the above-described method change processing (the IO request transfer method->the dual management method) S2400, when data is replicated from the second page to the first page, differential information relating to the update of the second page is managed and the differential information is reflected on the first page and the second page after the aforementioned replication is completed (S2415 to 2426). Thus, the shift to the dual management method can be made after the contents of the first page and the second page are surely updated to the, latest state. Accordingly, the shift from the IO request transfer method to the dual management method can be made without affecting the services to the host computer **2**.

As above, the embodiments of the present invention have been described. However, the embodiments are for facilitate understanding of the present invention, and are not to provide limited interpretation of the present invention. The present invention may be modified or improved without departing from the gist thereof and equivalents of the present invention are also included in the present invention.

For example, in the above description, the data management method and the operation mode are set page units. However, the operation mode may be set in units of storage apparatuses **10** or LDEVs. Also, the operation mode may be determined based on the load on the entire storage apparatus **10** or the load on all LDEV s.

The invention claimed is:

1. A storage system coupled to a host computer, comprising:

a first storage apparatus including a first logical volume associated with a virtual volume, and configured to provide the first logical volume to the host computer as the virtual volume; and

a second storage apparatus being coupled to the first storage apparatus, having a second logical volume associated with the virtual volume, and configured to provide the second logical volume to the host computer as the virtual volume,

wherein the first storage apparatus, when receiving a first write request for the virtual volume, is capable of performing a processing for the first write request by one of a first write processing method and a second write processing method,

wherein the first storage apparatus is configured to process the first write processing method by which a processing of storing write data relating to the first write request in the first logical volume is executed as well as the first write request is transferred to the second storage apparatus to store the write data in the second logical volume in the second storage apparatus,

wherein the first storage apparatus is configured to process the second write processing method by which the first write request is transferred to the second storage apparatus to store the write data in the second logical volume in the second storage apparatus without executing the processing of storing the write data in the first logical volume, and

wherein the first storage apparatus is configured to

acquire a first IO load for a predetermined area of the virtual volume in the first storage apparatus, and a second IO load for the predetermined area of the virtual volume in the second storage apparatus;,

select either the first write processing method or the second write processing method by comparing the first IO load and the second IO load with a threshold; and

perform a processing for the first write request using the selected processing method.

2. The storage system according to claim **1**, wherein

the first storage apparatus is further capable of performing a processing for the first write request by a third write processing method by which a processing of storing the write data in the first logical volume is executed without transferring the write request to the second storage apparatus; and

the first storage apparatus is configured to perform a processing for the first write request by a method selected from among the first write processing method, the second write processing method, and the third write processing method according to a first IO load for the predetermined area of the virtual volume in the first storage apparatus, and a second IO load for the predetermined area of the virtual volume in the second storage apparatus.

3. The storage system according to claim **2**, wherein

the first storage apparatus is configured to perform a processing for the first write request by the first write processing method when the first IO load is greater than a first upper limit threshold and the second IO load is greater than a second upper limit threshold.

4. The storage system according to claim **2**, wherein

the first storage apparatus is configured to perform a processing for the first write request by the first write processing method when the first IO load is greater than a first upper limit threshold and the second IO load is greater than a second upper limit threshold, and further a first read load is greater than a first read upper limit threshold and a second read load is greater than a second read upper limit threshold.

5. The storage system according to claim **2**, wherein

the first storage apparatus is configured to perform a processing for the first write request by the second write processing method when the first IO load is less than a first upper limit threshold and the second IO load is greater than a second upper limit threshold.

6. The storage system according to claim **2**, wherein

the first storage apparatus is configured to perform a processing for the first write request by the third write processing method when the first IO load is greater than a first upper limit threshold and the second IO load is less than a second lower limit threshold.

7. The storage system according to claim **2**, wherein

the first IO load is a number of IO requests per unit time for the virtual volume that the first storage apparatus receives;, and

the second IO load is a number of IO requests per unit time for the virtual volume that the second storage apparatus receives.

8. The storage system according to claim **2**, wherein

the first storage apparatus is configured to manage the first IO load in units of pages, being a unit storage area, included in the virtual volume;

the second storage apparatus is configured to manage the second IO load in units of the pages, being a unit storage area, included in the virtual volume; and

the first storage apparatus is configured to perform a processing for the first write request by a method selected from among the first write processing method, the sec-

ond write processing method, and the third write processing method according to the first IO load and the second IO load in units of pages included in the virtual volume.

9. The storage system according to claim **2**, wherein

the second storage apparatus is configured to perform a processing for a second write request as received for the virtual volume by the first write processing method when the first storage apparatus performs a processing by the first write processing method for the first write request to the virtual volume received by the first storage apparatus;

the second storage apparatus is configured to perform a processing for a second write request as received for the virtual volume by the third write processing method when the first storage apparatus performs a processing by the second write processing method for the first write request to the virtual volume received by the first storage apparatus; and

the second storage apparatus is configured to perform a processing for a second write request as received for the virtual volume by the second write processing method when the first storage apparatus performs a processing by the third write processing method for the first write request to the virtual volume received by the first storage apparatus.

10. A method of controlling a storage system including

a first storage apparatus including a first logical volume associated with a virtual volume, and providing the virtual volume and

a second storage apparatus being coupled to the first storage apparatus, having a second logical volume associated with the virtual volume, and providing the virtual volume, the method comprising:

the first storage apparatus, when receiving a first write request for the virtual volume, performs a processing for the first write request by one of a first write processing method by which a processing of storing write data relating to the first write request in the first logical volume is executed as well as the first write request is transferred to the second storage apparatus to store the write data in the second logical volume in the second storage apparatus, and a second write processing method by which the first write request is transferred to the second storage apparatus to store the write data in the second logical volume in the second storage apparatus without executing the processing of storing the write data in the first logical volume,

wherein the first storage apparatus acquires a first IO load for a predetermined area of the virtual volume in the first storage apparatus, and a second IO load for the predetermined area of the virtual volume in the second storage apparatus;

selects either the first write processing method or the second write processing method by comparing the first IO load and the second IO load with a threshold; and

performs a processing for the first write request using the selected processing method.

11. The method of controlling a storage system according to claim **10**, wherein

the first storage apparatus further performs a processing for the first write request by a third write processing method by which a processing of storing the write data in the first logical volume is executed without transferring the write request to the second storage apparatus; and

the first storage apparatus performs a processing for the first write request by a method selected from among the first write processing method, the second write processing method, and the third write processing method according to a first IO load for the predetermined area of the virtual volume in the first storage apparatus, and a second IO load for the predetermined area of the virtual volume in the second storage apparatus.

12. The method of controlling a storage system according to claim **11**, wherein

the first storage apparatus performs a processing for the first write request by the first write processing method when the first IO load is greater than a first upper limit threshold and the second IO load is greater than a second upper limit threshold;

the first storage apparatus performs a processing for the first write request by the second write processing method when the first IO load is less than the first upper limit threshold and the second IO load is greater than the second upper limit threshold; and

the first storage apparatus performs a processing for the first write request by the third write processing method when the first IO load is greater than the first upper limit threshold and the second IO load is less than the second lower limit threshold.

13. The method of controlling a storage system according to claim **11**, wherein

the first IO load is a number of IO requests per unit time for the virtual volume that the first storage apparatus receives; and

the second IO load is a number of IO requests per unit time for the virtual volume that the second storage apparatus receives.

14. The method of controlling a storage system according to claim **11**, wherein

the first storage apparatus manages the first IO load in units of pages, being a unit storage area, included in the virtual volume;

the second storage apparatus manages the second IO load in units of the pages, being a unit storage area, included in the virtual volume; and

the first storage apparatus performs a processing for the first write request by a method selected from among the first write processing method, the second write processing method, and the third write processing method according to the first IO load and the second IO load in units of pages included in the virtual volume.

15. The method of controlling a storage system according to claim **11**, wherein

the second storage apparatus performs a processing for a second write request as received for the virtual volume by the first write processing method when the first storage apparatus performs a processing by the first write processing method for the first write request to the virtual volume received by the first storage apparatus;

the second storage apparatus performs a processing for a second write request as received for the virtual volume by the third write processing method when the first storage apparatus performs a processing by the second write processing method for the first write request to the virtual volume received by the first storage apparatus; and

the second storage apparatus performs a processing for a second write request as received for the virtual volume by the second write processing method when the first storage apparatus performs a processing by the third write processing method for the first write request to the virtual volume received by the first storage apparatus.

16. The method of controlling a storage system according to claim 10, wherein

the first storage apparatus, when receiving an operation mode change instruction, reserves a storage area for a first page, and transmits a difference management start instruction;

the second storage apparatus, when receiving the difference management start instruction, starts management of differential information of a second page relating to an IO request received by the second storage apparatus, and transmits a difference management start notification;

the first storage apparatus, when receiving the difference management start notification, starts replication of data from the second page to the first page, and, when replication has been completed, transmits a completion notification;

the second storage apparatus, when receiving the completion notification, interrupts IO processing for the second page and updates the second page to a latest state based on differential information acquired so far, and transmits the differential information;

the first storage apparatus, when receiving the differential information, updates the first page to the latest state based on the received differential information, and transmits a difference reflection completion notification;

the second storage apparatus, when receiving the difference reflection completion notification, changes operation mode of the second page to a first mode and transmits a change instruction;

the first apparatus, when receiving the change instruction, sets the operation mode of the first page to the first mode, and transmits a change completion notification; and

the second storage apparatus, when receiving the change completion notification, restarts IO processing.

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